Luther Burbank

Artichoke Blossoms

Doubtless many people who eat the artichoke fail to realize that they are consuming a flower bud. But such is really the case. If the head with its many succulent bracts had been allowed to come to maturity, it would have been a composite flower, like the one here shown. But for use on the table, the bud must be plucked before it opens.

LUTHER BURBANK

HIS METHODS AND DISCOVERIES AND THEIR PRACTICAL APPLICATION

PREPARED FROM
HIS ORIGINAL FIELD NOTES
COVERING MORE THAN 100,000 EXPERIMENTS
MADE DURING FORTY YEARS DEVOTED
TO PLANT IMPROVEMENT

WITH THE ASSISTANCE OF
The Luther Burbank Society
AND ITS
ENTIRE MEMBERSHIP

UNDER THE EDITORIAL DIRECTION OF
John Whitson and Robert John
AND
Henry Smith Williams, M. D. LL. D.

VOLUME VII

ILLUSTRATED WITH
105 DIRECT COLOR PHOTOGRAPH PRINTS PRODUCED BY A
NEW PROCESS DEVISED AND PERFECTED FOR
USE IN THESE VOLUMES

NEW YORK AND LONDON
LUTHER BURBANK PRESS
MCMXIV

Volume VII—By Chapters

Foreword to Volume VII

This may be called the Vegetable Volume. In it, Mr. Burbank gives the details of his experiments in gardening, and an outline of his viewpoint, not alone for the benefit of the man who takes a lively springtime interest in his kitchen garden, but for the man, as well, who grows vegetables for the market.

Nor is attention directed solely to the commoner forms of garden vegetables, a wide range of hitherto unthought-of food plants being discussed as well.

In this volume will also be found a complete history of Mr. Burbank's work with the potato and a sketch of the improvements, which, for more than forty years, he has been striving to make, together with his suggestions to those who would like to take up the work of bettering this important crop.

THE EDITORS.

The Important Root Hairs

This picture shows a germinating seed that has thrown out roots which, even at this early stage, are provided with root hairs which, penetrating the soil, serve as mouths to take up moisture laden with nutrient salt. Root hairs, so-called, are of course not hairs in the proper sense, but tiny filaments of protoplasm with thin walls through which the nutrient solutions readily circulate. Tiny as they are, they constitute a highly important part of the mechanism of the plant.

How to Get the Most Out of the Garden

A Preliminary Outline

OF course you have heard of the feat of growing a mango tree, as performed by the Hindu jugglers.

The trick consists, according to those who claim to have witnessed it, in causing a mango tree to grow to fair proportions before the eyes of the audience from a pot which at first contained no visible plant.

The plant appears first as a small sprout and then grows to tree-like proportions under the manipulation of the conjurer before the very eyes of the astonished witnesses.

I believe modern skepticism, aided by the camera, has demonstrated that what the juggler really does is to throw a hypnotic spell over his audience and to cause them to confuse the magic picture of his word-conjuring with actual vision. But even if we were to take the feat of mango

growing at its face value, it would still be no more miraculous, properly interpreted, than things we may observe everywhere about us — say in any vegetable garden—or that you may yourself perform at any time in your own room.

Suppose, for example, that you were to take a tiny seed no larger than a grain of sand, and place it in a bowl on the window-sill.

You may leave it there indefinitely and it will give no sign that it differs in any wise from the grain of sand.

Yet if you wish to perform a miracle along the lines of that alleged to be performed by the grower of the mango tree, you have only to pour a tumblerful of water over the seed. Then in due course a transformation will be effected. The little seed will germinate and put forth a sprout and a system of rootlets and lift its head into the air and presently develop a bud that will swell and open into a beautiful flower.

This, surely, is a feat of conjuring that more than duplicates the alleged miracle of the Hindu fakir even though we were to take that performance at its face value.

To be sure, we have required more time for our miracle than he required for his; but what, after all are a few days more or less in the performance of such a feat? And, indeed, are we not

entitled to a little latitude of time considering that our miracle, which includes the creation of a beautiful flower, is so much more wonderful than his?

Perhaps you are inclined to demur, and to say that your miracle of flower-growing is no miracle at all because *you* had nothing to do with the matter. The growing of the plant, with its ultimate production of the flower, you will perhaps allege, was altogether the work of nature; a work in which you had no share.

Not so; for had not you supplied the cupful of water, nature would have been as powerless to transform the seed into a flower as you would be to transform the water into a flower without the aid of Nature.

Your feat of jugglery, like that of any other conjurer, required appropriate paraphernalia and the aid of an accomplice.

You chose as paraphernalia a tiny seed and a cup of water; and for accomplice you chose Nature herself.

You invoked the aid of natural laws, just as every other conjurer must do; and the results you finally achieved were surely more wonderful, more mysterious, more inexplicable than the results of any other kind of trick that human ingenuity could devise.

In effect, you held a cup of water before your

audience, waved your hand over it with magic incantations, and transformed the water into an exquisitely petalled and perfumed blossom.

Who could ask to witness a more marvelous feat of jugglery than that?

Yet such miracles as this are matters of everyday observation with the gardener. Is it strange that he finds peculiar fascination in his work and sees in his plants something more than the mere combinations of root and stem and tuber and seed-pod that they present to the casual observer? Rather to the gardener who goes about his task with the right spirit must every plant appear as the most wonderful of laboratories in which miracles of transformation, outmatching the utmost feats of the most skillful conjurer, are being performed every hour.

The All-Importance of Water

I have chosen the imagined incident of the flower seed grown in the bowl on your window-sill because I wished to emphasize the important principle that the one essential element without which no plant can maintain life or take on growth is water.

The plant grower has always given much heed to soil. He talks of sandy loams and clayey earth, and of humus and fertilizers. And all these, as we shall have occasion to see presently, have vast

Baby Plants

The leaf-like appendages put forth from a germinating plant when it first comes from the ground are called cotyledons. The entire coteries of higher plants are divided into two great classes, accordingly as their germinating stalks put forth one or two cotyledons. All the plants with which one deals in the garden are di-cotyledons, like those here shown. The cotyledons are uniformly smooth in contour (Mr. Burbank has seen but a single exception to this in his entire experience), and they serve as a reserve supply of food while the young leaves are getting under way.

importance. Yet in the last analysis the constitution of the soil—the very existence of the soil itself — is of incidental or subsidiary significance only in the plant economy. The richest soil that was ever prepared would not grow a single blade of grass or the tiniest weed if that soil were absolutely dry.

Nor could the hardiest weed maintain existence for a single day if transplanted into a soil, be it never so rich, that is absolutely devoid of moisture.

There must be water in the soil, to dissolve out and transfer its elements, in order that the rootlets of the plant shall be able to make the slightest use of these elements. Every essential constituent of plant food may be present in just the right proportions in soil that is packed about the roots of the plant with just the right degree of firmness, and yet the plant would perish as inevitably as if it were uprooted and suspended in the air, if there were not water present to bring the food materials into a state of solution.

But on the other hand, as we have seen, a plant may grow and thrive for a time quite without the presence of soil of any kind or quality if its roots are placed in water.

If we look a little farther into the intimate structure of the plant, utilizing the knowledge

Illustrating Leaf Structure

The leaf at the left presents the upper surface, and that at the right the lower surface. It will be seen that the upper surface is more smooth and glossy, in contrast with the more clearly ribbed and reticulated lower surface. The all-important stomata, or breathing pores, are largely located on the lower side of the leaf.

gained with the aid of the microscope and the studies of the chemist, we shall quickly come to understand why it is that water plays this all-important part in the functions of plant life. For it appears that the essential basis of life itself, namely, protoplasm, is a substance composed largely of water and having the physical constitution of a viscid liquid.

We find, moreover, that no particle of solid matter can, under normal conditions, penetrate the walls of the cells that make up the minute compartments in which the individual masses or protoplasm lie.

Ramifying everywhere among these are spaces and tubules that convey water and air. And portions of this water and air are absorbed by the bits of protoplasm through their cell walls.

With the water they gain the mineral constituents that are essential for their nourishment. But these include no minerals that are insoluble.

It is true that the plant rootlets may on occasion secrete certain fluids that aid the water in bringing into solution some intractable chemicals. But these secretions themselves are watery fluids and they would be ineffective if there were not water present to complete the work that they begin.

In a word, then, the all-essential element for which provision must be made by the gardener or

other plant developer is water. Where water is present, anywhere in the world, we find plant life luxuriating. Where it is absent, we find the deserts. There is no acre of soil anywhere that might not produce its crop of vegetation if properly watered. And, on the other hand, some of the richest soils in the world are those that are absolutely barren and fully merit the designation of desert lands because water is lacking.

Of course the gardener in many regions is supplied with water in adequate quantity for his plants by the natural rainfall and may disregard the question of artificial irrigation. But even in regions where the rainfall is usually adequate, there are almost certain to come periods of drought and the wise gardener who wishes to make sure of his crop will make provision for the meeting of this emergency.

Even where the soil is fairly moist, it is often possible to force the growth of a plant by additional watering.

You may readily test this for yourself by the free watering of alternate plants in a row in a time when the rainfall is only moderate. You may thus produce giants and dwarfs, say in a row of tomatoes, from the same lot of seed, under conditions which are absolutely identical except as to the matter of water supply.

Leaves by the Acre

Probably no one ever had time and patience, or thought it worth while, to measure the leaf surface exposed by the total foliage of a large tree. But one may readily enough measure a few leaves, and make an estimate; and it then appears that the leaf surface of a good sized tree must be measured in acres. When we reflect that the breathing pores are scattered thickly over the under surfaces, and sometimes over the upper surfaces also, of the leaves, and reflect that under normal circumstances each pore is taking in air and giving out moisture, it no longer seems surprising that a tree must send its roots far into the earth in search of water, or that the carbon taken from the air can build up as rapidly as it is observed to do the bulk of the tree trunk. A few leaves spread out together, as in the picture, give one a realizing sense of the way in which the surfaces take up space. Remember, too, that each leaf has a lower surface, doubling the area here exposed.

Of course it is possible to overdo the matter, super-saturating the soil and so shutting off air from the plant roots. But that aspect of the subject will claim our attention in another connection.

How the Plant Uses Water and Air

If we would have a clear comprehension of the function of water in a plant, we must go a little more fully into the physiology of plant growth, following the water, with its salts in solution, from the rootlet by which it is absorbed up through the stem of the plant to the leaf.

In an earlier chapter something has been said as to the forces that operate to make the water rise in seeming defiance of gravitation from the root to the leaf system of a plant of whatever size. The rise of the watery juices in a garden plant does not seem, perhaps, quite as mysterious as the rise of the sap in a tall tree. But there is no difference in principle. The laws that govern the movement of the sap are quite the same in each case.

We saw that there is reason to suppose that the principle of osmosis, acting between the cells, has an important share in transferring water from one cell to another, and ultimately, step by step, from the root to the topmost leaf.

It should be added, however, that the entire subject of the rise of sap in the tree has been matter for debate, and that there is not entire una-

nimity among plant physiologists as to the forces that are involved. That osmosis has a share, no one doubts. But it is alleged that the principle of capillarity through which liquids are drawn into minute tubes also has a share in elevating the water in the plant.

And it is further suggested that the constant transpiration of water from the leaves of the plants acts as a sort of suction force drawing the water upward. It should be understood, however, that this alleged suction power, when analyzed, is nothing more than a drying out of the cells of the leaf which makes them more absorbent and thus brings into play the principles of osmosis and capillarity through which they take up a new supply of water from neighboring cells.

Thus, properly understood, the effect of transfusion of water from the leaves is to be interpreted in terms of osmosis, and capillarity.

So also must be interpreted the so-called root pressure through which water is forced upward into the stem of the plant at a time when the plant has no leaves—as in case of a tree in the early spring time. Such root pressure undoubtedly exists, but this also is explicable as due to the absorption of salts in solution by the rootlets from the water in the soil about them, leading to osmotic action between these superficial cells and the ad-

Where the Tree Is Alive

This section of the trunk of a small tree is pictured in such a way as to expose the Cambium layer, just beneath the outer bark. In this layer are located all the protoplasmic cells, aside from those in the leaves, that are really alive. A portion of the woody tissue just beneath the Cambium conveys the watery solution upward from the roots; but the return flow of sugary sap takes place solely in the Cambium layer, where also the protoplasmic or life activities go on, through which the tree grows; growth itself being due to the deposit of what is virtually waste material from the cell. The central wood fibers of the trunk are totally dead.

joining cells, which in turn pass the water, with its modicum of nutrient salts, to yet deeper layers of cells, and ultimately up along the stem of the plant or tree—constituting the familiar phenomenon of the "rise of sap."

Regardless of the precise explanation, however, the fact is obvious and long familiar that water bearing a certain quantity of minerals in dilute solution is absorbed by the roots of the plant and is carried up in due course to the ultimate buds and growing tips and leaves.

It has been known for a good while also that the leaves of the plant have on their under surface vast numbers of little mouths or stomata, through which a certain amount of the water that has come to them from the roots is transpired or exhaled, and through which also air is inhaled.

But it has only somewhat recently been learned that the air which thus enters the structure of the leaves is transmitted everywhere throughout the tissues of the plant, through little crevices or canals that may be likened to the bronchial tubes of an animal or of man, except that they are infinitesimal in size.

Through these channels, air is brought in contact with all the cells of the plant, and, during periods of growth, there is a constant, even though slow, interchange between the air in the inter-

Mr. Burbank's Ideal Soil

Such piles of soil as that here shown are always at hand in and about Mr. Burbank's greenhouse. The soil consists of about fifty per cent. of clean, rather coarse, sharp sand; forty per cent. of good pasture or forest soil, containing leaf mold; and about ten per cent. of finely ground moss. This makes an ideal soil for the seed boxes, and seeds of any and every kind may be germinated in it.

cellular spaces and the structure of the protoplasm within the cells.

This interchange includes the absorption of oxygen and the giving out of carbonic acid on the part of the plant cell, which is precisely the same thing that occurs in the functioning of the cells in the tissues of an animal. In point of fact the essential properties of protoplasm are the same, whether that protoplasm is found in the tissues of a plant or in the tissues of a man.

Plants, like animals, in breathing take in oxygen and exhale carbonic acid gas.

Plant Cells and Animal Cells

This fact, as was said, has not been clearly understood until somewhat recently.

The phenomenon of the absorption of oxygen and the exhalation of carbonic acid has been obscured in the case of the plant by the further fact that the plant leaf absorbs constantly from the air during the daytime, under the influence of light, a relatively large quantity of carbonic acid gas from the minute quantity in the air, so that the net result is that it takes up from the air more carbonic acid than it exhales.

It was only by studying the plant in the dark, when the elaborate processes through which it utilizes the excess of carbonic acid are in abeyance, that the fact of the close analogy between

vegetable protoplasm and animal protoplasm as to the ingestion of oxygen and the giving out of carbonic acid as a waste product was demonstrated.

Now it is known, however, that the protoplasm of a plant cell, as it exists in the root and trunk of a tree, for example, and indeed in any part of a plant where there is no green matter, not only functionates in the same way as the protoplasm of animal cells, in regard to absorbing oxygen and giving out carbonic acid, but that the two have precisely the same food habits in general.

The average plant cell, as it exists in the root or stem of the plant, is in precisely the same position as the cells of an animal, in that it can secure nourishment only from food that has been prepared in a particular way.

It can no more take a crude solution of mineral salts and extract nourishment from them than can the animal cell.

All the necessary constituents that go to make up the best food may be present, but neither the plant protoplasm nor animal protoplasm can make use of these constituents unless they have been compounded in a unique and extraordinary way.

But when we consider the matter one stage farther we come upon this vital difference: the

Transplanting Selected Seedlings

Here some seedlings grown in the ideal soil in Mr. Burbank's regulation type of "flat" are being transplanted at a very tender age. The process is very simple, being effected with the aid of a knife blade, as the picture clearly shows. There is no particular rule about it, except to be sure that you get all the roots of the tiny plant.

plant, unlike the animal, has provided a special mechanism—a unique laboratory—through which it is able to manufacture from the crude salts in watery solution, with the aid of another element taken from the air, a new compound which will serve the protoplasmic cell with food.

That is to say, the plant organism as a whole, comprises a laboratory for compounding the crude elements, which by themselves cannot be used as nourishment, into a substance that can be used as nourishment.

Stated in slightly different terms, every well-organized plant has a food factory as part of its regular equipment.

Here indeed is a difference and a very vital one between the plant and the animal. For no animal is equipped with such a food factory as this.

And when we add that the food factory of the plant is the only place in the world where food stuffs are manufactured, and that no animal of any kind could live an hour without nourishment that was originally manufactured by some plant, the vital importance of the matter will be manifest.

The Plant's Food Factory

Now of course the plant in operating its wonderful food factory is functioning to supply its own needs.

It must supply nourishment to the multitudinous cells that make up its root and stem and branches, which, as we have seen, are quite incapable of extracting nourishment from the crude salts in solution that they are constantly transporting.

But incidentally, in manufacturing food for its own cells, the plant is producing a supply of food that will be available for the sustenance of animal cells also. Thus the entire animal world may be said to be a vast parasitic colony as absolutely dependent upon the vegetable colony for its essential food supplies as any other parasite is dependent upon its host.

When we consider the matter in this light, it is pretty obvious that about the most interesting thing in the world, from the standpoint of animal economy—which of course includes human economy—is the wonderful laboratory or factory of the plant where alone is effected the transformation of the crude inorganic elements into such combinations as are available for the sustenance of life.

When we reflect that the plant laboratories in which this wonderful and vitally essential transformation is effected are chiefly located in the leaf of the plant, it appears that the thoughtful person must regard this structure—the most ordinary

Selected Seedlings

The little plants in this "flat" have been transplanted with a knife blade, as shown in the preceding picture, to give them an opportunity to show their possibilities. They are set out carefully in rows—for Mr. Burbank's work is always neat and artistic; but the new soil does not differ from that in which they were germinated. The only difference is that here the plants are no longer crowded, and each can be given individual attention. The comparatively few individuals here shown may be all that are left from the scores of "flats" that originally germinated thousands of seedlings.

green leaf of tree or shrub or vine or the tiniest blade of grass—as in some respects the most wonderful thing in the world.

When the wise plant developer goes into his garden or orchard, therefore, his eyes turn always first and foremost to the leaves of the plants with which he works.

The reader will perhaps recollect that over and over I have called attention to the predictions that may be made as to the future fruiting powers of a given plant—apple seedling or pear seedling or grape seedling or what not—from observation of the leaves. The reason for this will now perhaps be more apparent. It will be still more clearly evident if we inquire a little more in detail as to the exact processes that take place within the structure of the leaf-laboratory in which is brought about the all-essential manufacture of food on which the future growth of the plant itself and its fruiting possibilities must absolutely depend.

No one needs to be told that all normal leaves are green in color. But perhaps it may not have occurred to you what a really remarkable fact this is. The trunks and branches and roots of plants may vary widely in color; and flowers and fruits may show all diversities of the rainbow. But from one Arctic circle to the other and around the circumference of the globe, plants of every tribe

(with the rare exception of parasites which take food predigested by the green plants), from the minutest creeper to the most gigantic sequoia or palm or eucalyptus, have leaves of the same primary color.

And the reason for this is that the leaf derives its color from the massed effect of little structures called chlorophyll granules that nestle in its individual cells, constituting the really essential part of its food-forming laboratory. These have adopted a green uniform as the insignia of their office, and they hold as rigidly to this color as if their very lives depended upon it. And for aught we know to the contrary, their lives may depend on it; for no one has yet been wise enough to say just what relation the color bears to the wizard-like powers of the so-called chlorophyll granules that wear it, and that, seemingly with its aid, effect the marvelous transformation of inorganic elements into food-stuffs of which they alone of all created things are capable.

As I say, no one knows just what relation the green color of the chlorophyll granules bears to their work because no one knows just how their work is performed.

That is to say no one at all understands why it is possible for the plant cell that bears within its substance one of these green chlorophyll bodies to

Inspecting a Root System

Should a question arise in Mr. Burbank's mind as to why a particular plant is not thriving just as it ought, he may "go to the root of the matter" in a literal sense, to see if he can find out what is wrong. Of course such an examination must be made very carefully, and it is not to be recommended as regular treatment for many plants, but on occasion it may be of service to dig into the ground beside the plant, and find out how its roots are getting on. A young plant with defective roots is in precisely the position of a child with very bad teeth,—it cannot possibly get proper nourishment.

combine certain inorganic elements into nutritious foods, a feat that no human chemist can perform.

But on the other hand, we do know, thanks to the analysis of the chemist—who can sometimes tear things to pieces and find out what they are made of even when he cannot put them together again—what the chlorophyll granule accomplishes, even though we cannot understand just how or why it is able to perform its work.

Chlorophyll at Work

What takes place within the structure of the leaf, then, with the aid of the wonderful green workmen, is this: A certain number of molecules of water, brought to the leaf from root and stem, are taken in hand and compounded with a certain number of molecules of carbon extracted from the air that has been brought into the leaf laboratory through its mouths or stomata from the outside atmosphere.

When the compound has been effected, we still have the atoms of hydrogen and oxygen that composed the water molecules and the atoms of carbon, but they are so marvelously put together that they no longer constitute the liquid water or the gas in which the carbon was imported. They now constitute an altogether new substance which is termed sugar.

Thus only three elements are dealt with and

these very familiar ones. It would seem as if almost any chemist should be able to manage a simple combination like that. But in point of fact no human chemist knows how to manage it. There are forces to be invoked in effecting that combination of which no chemist has any knowledge.

Only the chlorophyll grains in the plant leaf have learned the secret, and up to the present they have kept their secret well.

There are other feats of atom-juggling performed with the new compound that are wonderful enough. For example, the sugary compound is ordinarily transformed, in part at least, into granules of starch to be stored away for safe keeping. And this transformation implies a bit of juggling that is by no means easy. But after all it is only the changing of one organic compound into another, and the human chemist can do some extraordinary feats in that line. The really wonderful work done in the leaf laboratory is the original transformation of inorganic materials into an organic compound.

Of course there are other important stages of the work through which final assimilation is accomplished. To make starch or sugar into protoplasm it is necessary to bring another element into the combination. This element is nitrogen. There must also be incorporated small quantities

Artificial Rain in Mr. Burbank's Garden

The kind of sprinkling apparatus that Mr. Burbank uses and recommends is that here shown. It consists of long pipes, attached to a hose, the pipe having little nozzles at intervals of a few inches, and thus sending forth a series of tiny streams which, rising high in the air, descend on the plants in a shower that closely simulates rain from the clouds. The pipes can be turned to throw the spray in either direction, and to regulate the distance at which the shower descends. Remember always that water is food for the plants,—absolutely indispensable food.

of a number of minerals; notably compounds of phosphorus and potash and lime, but including six or eight others that must be present in infinitesimal amounts.

And the building of these substances into combination with the sugar in such a way as to produce the substance called protoplasm, the basis of all life, constitutes the culminating stage of the miracle. But the way in which this is effected is even less clearly understood.

We do know, however, that all these substances are brought to the plant in watery solution.

Nitrogen constitutes about four-fifths of the atmosphere, as everyone knows, and hence it seems rather strange that the plant does not draw what nitrogen it needs from this source, in particular since it gets its carbon from the air.

But in point of fact the plant, no less than the animal, might starve to death from lack of nitrogen even while its tissues are everywhere bathed in nitrogen gas. To make the nitrogen available for the purpose of nutrition it must be made into soluble compounds called nitrates, and must be supplied in dilute watery solution.

Such nitrates, therefore, are among the most important of the soluble compounds that must be contained in the medium surrounding the roots of the plant. Sucked up by the rootlets in dilute

A Beautiful Thief

The mistletoe has green leaves, and so is able to take carbon from the air, and to manufacture sugars and starches. But it sends its roots into the bark of a tree, and draws its moisture and part of its nourishment from the cambium layer and sap-wood of its host. The seed of the mistletoe is covered with a very sticky pulp (used sometimes for making bird-lime), which adheres to anything it touches, and so is likely to find appropriate lodgment on the trunk of a tree. Should it fall to the ground instead, its days are numbered.

solution, along with much smaller quantities of phosphorus and potash and the other essential minerals, it is carried to the plant cells and ultimately compounded with sugars made in the leaf laboratory to make living protoplasm and thus to promote the growth and development of the plant.

The Finished Product

This protoplasm is, of course, in the last analysis *the* vitally important substance. Without it there is no life. Even the chlorophyll body is itself a protoplasmic substance and establishes its workshop in a protoplasmic cell. All the life processes — growing, flowering, fruiting — are linked with the protoplasmic activities, just as are all the life processes of animals of every kind.

But from the standpoint of the gardener, which furnishes our present outlook, interest may be said to center on the production of the non-nitrogenous carbon compounds, starch and various sugars, the creation of which in the leaf of the plant we have just witnessed. For the chief products of the vegetable garden (with the notable exception of peas and beans) contain only a small proportion of the nitrogenous matter which the food specialist names protein. We depend for our nitrogenous foods largely upon the animal world.

The products of the vegetable garden are stores chiefly of carbohydrates, that is to say of starches

and sugars. These make up the chief bulk of such tubers and roots as potatoes and carrots and parsnips, and the main nutritious matter of the principal garden vegetables, except, as just intimated, that peas and beans have a relatively high proteid or nitrogenous content.

After what has been said, it will be understood that the starch and sugar content of the potato, for example, is not developed in the tuber itself, but is manufactured in the leaf of the plant and is then carried down in the elaborated sap that runs as a sort of return current to the roots and is there deposited for the uses of the new plant next season.

In the case of the carrot and parsnip, the same thing, of course, is true. Here a large root, with its deposit of starch and sugar, is designed to live through the winter and next season to supply such nourishment for the plant as will enable it to take on rapid growth and to develop a large quantity of seeds. These plants are biennials and do not fruit in their first season. It is this fact that has been taken advantage of by man in developing their roots and diverting them to his own uses.

Principles versus Methods

In all this, it will appear, we have said nothing as to practical methods of gardening. But I have thought that a clear outline of the principles involved in the all-important matter of the nutrition

of the plant, and in particular a full presentation of the reason why the leaf structure of the plant is of paramount importance, might serve better to prepare the would-be gardener for his task than a mere categorical citation of methods, unexplained as to their final purpose.

Whoever has carefully followed the outline just given will have a clear notion of the needs of the plant and might depend, were it necessary to do so, on his own ingenuity to devise means for meeting these needs.

But, as a matter of course, we shall have occasion to deal more at length with specific methods of procedure with reference to the different types of garden vegetable when we take up in successive chapters the story of my work in the development of plants of the vegetable garden. And the general methods of soil preparation, drainage, irrigation, and fertilization are elsewhere treated in detail.

—I wish to emphasize the important principle that the one essential element without which no plant can maintain life or take on growth, is water.

Some Common Garden Plants and Their Improvement

Half Hour Experiments With Many Plants

NOTWITHSTANDING the large number of garden vegetables, all the common forms fall into a few groups.

Thus there is the great family of melons and squashes, technically known as the gourd family, which gives us such familiar vegetables as the gourds and squashes, the pumpkin, the watermelon, and muskmelon, and the cucumber.

Then there are the cabbages of various types, with which is botanically associated the turnip, and with which the gardener will also associate the familiar lettuce plant.

Another group includes the familiar root vegetables, the carrot, parsnip, and radish. These have a characteristic manner of growth, demand somewhat the same texture of loose, sandy soil, and respond to the same treatment.

In a quite different class are the peas and

beans, which, in all their varieties, are obviously related to one another and quite as obviously distinct from all the other members of the garden coterie.

The onion and its allies may be recognized as constituting a class of vegetables that supply savor rather than nutritious principles. From the standpoint of the gardener there may be listed a number of less familiar plants to make up the category of vegetables that are grown merely because of their appeal to the palate and for the flavor that they impart to other foods rather than for their genuine food value.

Two other prominent plants which complete the list of the ordinary garden vegetables of greatest popularity are classed together by the botanist, and indeed are to casual observation closely similar in foliage, yet so distinct as to the character of their product that the gardener would never think of associating them. These are the potato and the tomato—own cousins—notwithstanding the widely different character of the food products they supply.

Some of the plants just named will be given individual treatment in successive chapters of the present volume. But two or three companies, including a wide range of species and varieties, may be grouped together here as illustrating, jointly

An Attractive Melon

That these improved canteloupes are of good quality, might have been predicated from inspection of their surfaces. A musk-melon with a closely netted or reticulated surface like this is usually a good one. There appears to be some coordination between the fineness of the network on the surface and the sweetness and juiciness of the flesh. There is no very obvious reason why this should be so, unless, as is probable, horticulturists have found the reticulation attractive, and have selected for this quality.

and severally, the methods of the plant developer when applied to garden vegetables, and as offering interesting possibilities of development for the amateur gardener.

The Melon Family

At the outset we may consider the melons, partly because the product that they offer the gardener may be said to occupy an intermediate place between the fruits proper, as grown in the orchard, and what are commonly spoken of as garden vegetables. The melons are, indeed, fruits of a distinctive order. They seem of unique type to us merely because our point of fact is that of residents of a temperate zone. In tropical regions, fruits like the melons abound, the family to which the melon belongs being a very extensive one, represented in the aggregate by several hundred species.

The most generally cultivated member of the melon family in the ordinary kitchen garden is doubtless the form known as the cucumber. The ordinary cucumber has long been under cultivation and has been greatly improved, especially in Europe. It has been made to take on various forms of fruit, and the best varieties have been practically relieved from the spines with which the plant was originally endowed, and partially also of the seed.

The Familiar Cucumber

Perhaps no other member of the melon family is so familiarly known and so universally appreciated as the cucumber. This is rather surprising, considering that the vegetable has a bad reputation as regards digestability, when eaten in the green state. The vast majority of cucumbers, however, are used as pickles; and when properly prepared they are at once savoury and wholesome. The cucumber under cultivation is a very thrifty plant, fa[illegible] less finical than its c[illegible]s, the watermelon [illegible] the muskme[illegible]

The common cucumber may be crossed with the variety known as the Russian cucumber, but in general this plant proves its individuality by refusing to hybridize with its not very distant relatives, such as the melons. But the other members of the family hybridize readily. Indeed there is so little difficulty in crossing them, that it is necessary to plant the different species in widely separated rows to prevent accidental hybridization through the agency of the bees.

With the cucumber there is no such difficulty. In our experience it refuses to hybridize with other melons. Doubtless because of its lack of affinity for other species, the cucumber is relatively easy to fix as to new varieties, differing very markedly in that respect from the squashes and gourds.

The so-called snake cucumber is in reality a muskmelon. It will cross readily with the other varieties of muskmelon. The product, however, is inferior, considered either as a cucumber or as a melon. The banana melon is probably a cross between the snake cucumber and some other muskmelon; or it may have originated from the same source as the snake cucumber itself.

The banana melon has been improved by selection until in some varieties it is a fairly good melon, although generally lacking the high flavor of the cantaloupe and other specialized musk-

melons Some varieties of these so-called snake cucumbers attain a length of three or four feet, and coil up in such a way as to resemble a serpent, justifying their name.

A form of melon introduced, I believe, from Syria, and known as the Santa Claus melon has interest because it keeps well until mid-winter. It is a longish oval muskmelon, with red and green stripes. Its chief demerit is that it is variable in quality, some specimens being of delicious flavor and others distinctly inferior. It has the further fault of cracking seriously.

In working with this variety during the past few years, I have succeeded in largely eliminating its faults, and in so doing have produced a type that might be considered a new variety. My work with the species has been entirely along the line of selection, for I knew the danger of producing too great variation by hybridizing the members of this family and the almost impossibility of fixing any variation. Most forms have originated by hybridization at no remote time in the past, and it is far better to work with them by selecting individuals that are observed to vary rather than by attempting to produce wider variation. By this method alone I was enabled in a few years to develop a form of the Santa Claus melon that was considered worthy of introduction. The company

A Visitor From Patagonia

Mr. Burbank has done a good deal of experimenting in the way of developing a variety of Patagonian squash that gave great promise, and ultimately justified the hopes based on its early appearance. A specimen is here shown growing in Mr. Burbank's garden.

that purchased it have renamed it the Florida, and are planning to grow it along with other products on a large tract in Florida.

Not only is it necessary to keep the muskmelons in different parts of the garden to prevent crossing through the agency of insects, but it is also necessary to be exceedingly careful in selecting the seed year after year, saving only that from vines that come true to type. Otherwise the stock soon runs out and comes to lack individuality of form and flavor of fruit. This is because the muskmelons have been cultivated for a very long period and have developed many varieties that have constantly been more or less crossed.

This mixed heredity is likely to make itself manifest in the progeny of any generation, and constant attention is necessary if a type is to be kept pure.

The muskmelon grows best on sandy land, and of course a warm climate is necessary to the perfection of the fruit. It acquires a particularly sweet, spicy flavor where the nights are warm as well as the days. In recent years the small, green-fleshed muskmelon, generally called cantaloup, has become exceedingly popular. The variety of melon known as the Casaba, which matures later in the fall and has peculiar lusciousness, is also much grown. This has been introduced from the

Syrian region in various forms, and it thrives particularly in dry climates like that in which it has grown for ages. It does not thrive in the moist eastern climates, but is better adapted to semi-arid conditions.

There are certain distinctive features of the different cantaloups and muskmelons to which the gardener should give attention. The light-fleshed ones should have light skins, and the dark-fleshed ones dark skins. The network on the skin is an important guide in seed selection, as a fine, completely netted melon usually is of better quality than one that is incompletely netted. These two conditions seem generally correlated, though not necessarily so. The flesh of the melon should be thick, and tender throughout, except that for shipping purposes it is sometimes desirable to have the flesh a little harder toward the skin.

The seed cavity should be small, and the seeds should be in a compact mass, occupying a minimum amount of space.

Now and again one hears of attempts made to grow seedless melons. A moment's reflection will show that this suggestion must be intended as a joke. The melons are annuals, and must be grown year by year from the seed. To eliminate the seed would be to exterminate the melon in a single season. The case is obviously very different from

Two Squashes in One

Here are two specimens of Mr. Burbank's perfected Patagonia squash. The one at the left presents the face that shows the very strange conformation of this vegetable. It looks as if two squashes had been grown together through some freak of nature; but in reality this is the habitual form of this curious vegetable. This peculiar conformation gives the squash a certain resemblance to a monster seedless navel orange.

that of fruit trees, which may be propagated by grafting, or of such plants as the horseradish and potato, the roots or tubers of which carry the species over from one season to another.

In raising melons, especially in colder climates where the seasons are short, it is desirable to use ammoniacal fertilizers to force the plants along rapidly. A liberal use of one of the nitric fertilizers will often double the crop or, indeed, insure a crop where otherwise the melons would not ripen.

The gardener who wishes to grow melons extensively will not overlook the pomegranates and so-called orange and pocket melons. These have interest because of their unusual appearance, even though they are somewhat lacking in quality. There are also large Persian and Syrian melons that are favorites not only for their delicious quality but also because they keep until late in the winter, even until the first of January with common storage. Probably in cold storage these melons would keep throughout the winter.

Unfortunately these Persian and Syrian melons are exceedingly variable as to quality. Some are fully equal to the best cantaloup, while others will be hardly edible.

The amateur gardener might find it a useful and interesting task to improve these melons in this regard by careful selection.

Some Experimental Gourds

The gourds, like their cousins the melons and squashes, are of tropical origin; but they thrive in any more temperate region where the summers are reasonably long and hot. Mr. Burbank has experimented extensively with many species, and a few typical specimens of gourds undergoing education are here shown.

The squashes, gourds, and pumpkins constitute a tribe of melons that differ from the watermelon and muskmelon in that their flesh is not edible until it is cooked.

There are great numbers of species of this tribe, a large variety of which are under cultivation. Among these are the forms colloquially known as crookneck, turbine squash, giant Chile Hubbard, bush scallop, and gourds of various types both ornamental and useful.

The pumpkins, grown often in the cornfield of the farmer but seldom in the garden, constitute a form of squash rather distinct from the others, as evidenced not only by their appearance but by the fact that they do not cross readily with the other squashes.

There is, however, a good deal of confusion in the use of the names pumpkin and squash in different regions. This is brought out prominently in California where a squash if grown for stock food is called a pumpkin, whatever its variety.

The earliest form of squash with which I worked was the winter or Canada crookneck, which in my boyhood was one of the most popular of squashes. It had run into several forms, one being of immense size with a short and heavier neck. The summer crookneck squash, also common at that time, was a long, bright yellow, warty

squash, grown for summer use. Another form, somewhat less familiar here but very popular in England, is the vegetable marrow. The scallop or Pattypan type of bush squash has also attained popularity in some regions, being an especially early variety.

There was a squash introduced some years ago under the name of cocoanut which was a splendid keeper, lasting from harvest time to harvest time, although not improving in quality after the first six months.

The Hubbard Squash

The Hubbard squash was introduced by J. J. H. Gregory, of Marblehead, Mass., and it is probably on the whole the best squash now under cultivation. It is of a very rich, sweet quality and is a splendid keeper. Mr. Gregory obtained the first seed of this squash from the garden of a sailor's widow, and no one has ever found the Hubbard squash in any other country except as introduced from this stock. It was never known where the sailor obtained the seeds that produced it.

Reference has been made to the ease with which the various squashes may be hybridized.

In point of fact it is necessary to grow squashes of different species at a distance of nearly a quarter of a mile or there is danger that they will be

cross-fertilized and the strains rendered impure. So of course the plant developer has no difficulty in effecting almost any cross he may wish. It is only necessary to take pollen from one flower and deposit on the pistil of another to have reasonable assurance that the cross will be effected.

But the results of such hybridizing are usually altogether disconcerting. The hybrid progeny seem to branch in every conceivable direction. A gardener of mine declares that hybridized squashes "go crazy", so widely varying are their forms and so little subject to prediction. Moreover, it is exceedingly difficult to fix any new type thus developed or to restore an old type thus disturbed by crossing.

Even if the hybrids do not vary greatly in the first generation they may become entirely chaotic in the second.

A classical illustration of this is furnished by some experiments of Prof. L. H. Bailey, who developed a variety by crossing that seemed to come reasonably true to type one year. Thinking the variety fixed he sold the seed to a prominent seedsman, and it was said that the following year no two specimens of the entire lot bore any close resemblance to each other.

This happened a good many years ago, and was so disconcerting as to lead Prof. Bailey for a time

Too Much Seed

This picture shows why the gourds previously shown are in need of education. They look very well on the outside, but within they are mostly seeds. The seeds of the melon tribe are not the part one seeks to cultivate, and this one must minimize its seeds and develop its pulp before it will have any value.

to question whether the laws of heredity apply to plants as they do to animals.

Needless to say all doubt on that subject was dissipated by wider observation. But the hybrid squash remains to this day one of the most difficult plants to fix as to any particular form.

Some very interesting and useful experiments might be made in the endeavor to sort out the unit characters that are mosaiced together to make up the squash. If it could be determined that there are pairs of unit characters governing important matters of size and quality, such as are found in so many other plants, an understanding of these as to their respective properties of dominance and recessiveness might enable the plant developer to hybridize the squashes and forecast the results of certain unions with a greater measure of assurance. But as yet little or nothing has been done in this direction.

My own work with the squashes has included hybridizing experiments on a somewhat extensive scale, more for the general interest of the subject than for the development of new commercial varieties.

I have produced, however, one somewhat important variety from seed sent by my collector in Chile. This is a variety the original of which somewhat resembled the acorn squash—having the

Some Gourds from Australia

As the reader is aware, Mr. Burbank sends all over the world for specimens to carry out any line of experiment in which it is desirable to introduce new hereditary tendencies, or stimulate variation, or test out unexplored possibilities. These Australian gourds are of interest because no one can say what may result when they are crossed with gourds from other continents. The results are likely to be notable, and they are sure to be of interest. Such tests are now being made in Mr. Burbank's gardens.

form of a rather irregular acorn in its cup, giving it a unique appearance. This is of very large size and it will grow on dry land where other squashes do not thrive, attaining a great weight.

The vines first grown from the seed showed evidence of mixed ancestry. But some of them gave such promise that it seemed worth while to sort out the best strains.

To effect this, I used hand pollenation and the most rigid selection. Only the specimens showing the desired qualities were used in the crosses, and only the best individuals preserved for seed.

In the course of a few generations a fairly fixed plant was thus produced. The most marked peculiarity of this squash was its exceptional specific gravity. For its size it was incomparably the heaviest squash I have ever seen. The meat is thick, solid, and of dark color. Its seed cavity is of medium size, thickly studded with large, heavy seeds. Exteriorly the squash is white, striped with green, generally but not always smooth.

This new variety found favor in many localities for planting in dry places or as a dependence in dry seasons. It was named the Chiloe by the company who introduced it, in recognition of the home of the ancestral stock from which it was developed.

The Freakish Martynia

The Martynia is a food plant that is not very familiar in our garden, but one with which Mr. Burbank has experimented rather extensively. The curious scheme adopted for the distribution of its seed by this plant is described at some length in Volume I, to which the reader is referred. In the tropical regions to which this plant is native, the struggle for existence is so sharp that it is necessary to take advantage of every possible opportunity, and each plant has its own way of endeavoring to get ahead of its neighbor.

Notwithstanding its cannon-ball like solidity, it is of exceedingly sweet flesh. Its firmness gives it remarkable keeping qualities; it often lasts until May or even June of the following season.

My work with this squash shows that it is by no means impossible to fix a new type. But there is abundant work to be done in this direction with large numbers of varieties now under cultivation. Much may be done also toward developing thickness of flesh and sweetness of quality. Moreover, attention should be given to the seed cavity, which may be made much smaller. The seeds cannot be altogether eliminated but their number might be advantageously reduced.

Again, varieties may be developed having shorter or more compact vines. There should be no great difficulty in attaining these ends, and the field is obviously one in which any amateur gardener may work with ease. The facility with which squashes may be hybridized gives them added attractiveness from the standpoint of the novice.

The Crucifer Family

The tribe of Crucifers is represented by a large number of annual and perennial herbs of wide distribution, the most conspicuous members of which are the cabbage and its allies.

It is supposed that all of the near relatives of

the cabbage are modified descendants of a single species that grows wild along the Mediterranean and Atlantic Coasts of Europe. Turnips are descended from another closely related species having the same habitat. The radish, horseradish, water-cress, and mustard are other members of the family that are not quite so closely related.

The members of this group occupy a position of considerable importance in the vegetable garden; chiefly, however, because of their various flavors rather than because of their nutritious value. There is comparatively little nourishment in the substance of any of them, except the cabbage.

From the standpoint of the plant developer, the members of the cabbage tribe have exceptional interest, not so much because of possibilities of future development as because of what they reveal of past development.

If, as is believed, they have all sprung from a single species and within comparatively recent times, they afford highly interesting illustrations of the varied lines of development that the offspring of a single plant may be induced to follow.

Thus the edible head of the cauliflower and broccoli consist in reality of thickened and consolidated flower peduncles. The edible part of the

The Familiar Beet

These exceptionally fine specimens present an improved variety of a plant that grows in every garden. Nowadays, however, the beet is not merely a garden vegetable, but a field plant of the very highest importance; inasmuch as it is the chief source of the world's sugar supply. Through selective breeding, the sugar content of the beet has been enormously increased within recent years, and this humble vegetable now outrivals the sugar-cane as a producer of sweets.

kale consists of expanded but tender leaves. Brussels sprouts are thickened buds developed in the axis of the leaves. The cabbage is merely a single monstrous bud, with its leaves unexpanded. And in the kohl-rabi—perhaps the most recently developed of all the garden vegetables—it is the short and few-leaved stems that become thick, bulbous, and edible.

Here, then, is a plant in the different races of which, the stem, the leaves, and the flowers respectively have been modified until they are edible monstrosities. Few other plants show such versatility; so the familiar colloquialism that dubs a dunce a "cabbage head" is obviously lacking in fitness of application.

If the cabbage tribe were to develop a member having an edible root, its versatility would be universal; and, indeed, a very near relative belonging to the same genus makes up the deficiency in this regard: for the turnip has about as much root in proportion to its size as a plant can possibly produce.

As might be expected, considering their origin, the different crucifiers vary greatly. The various cabbages and cauliflowers and Brussels sprouts may be hybridized with one another or with the strap-leaved turnips without difficulty.

But the result is usually a rather curious lot of

mongrels that have no utility, all apparently tending to turn back toward the wild parent form. Each member of the family has been developed to its present specialized form through many generations of selection alone; and the specialization is so great that there is small prospect of securing a useful form by bringing them together.

Such a development is not impossible, however, but it would certainly be difficult to fix the new type after it had been produced.

My own experience with the cabbage tribe was chiefly gained in the early day of my experimental work, nearly half a century ago. I discovered that it was easy to cross the cabbage with the cauliflower and with other members of the tribe; that, in fact, it is necessary to grow them quite a distance apart in order to keep the seeds pure. But the hybrids produced were all what we were accustomed to describe as mongrels. Some of them had small cauliflower heads of inferior quality.

At the time when these experiments were made I did not fully understand the importance of the second generation, and I have never found time to take this line of experiment up again.

I have had good success, however, in crossing the purple-leaved cabbage with other varieties of cabbage, developing thus a purple cabbage with

Another Old Friend

The radish can claim no such economic importance as the beet has now attained; but it is perhaps even more universally distributed in the gardens of the world. The specimens here shown illustrate very tangibly the wide variation of form among the different varieties that have been developed through selective breeding.

a very large head. They were somewhat less dark in color than the parent stock.

My work with the turnip has not extended beyond the stage of experimental crossing with the cabbages, which led to no prospect of useful results. With the radish, which might be described as a dwarf turnip, my work has been carried along the line of selection, without hybridizing.

There are enough variations among the seedlings of any given root to afford ample opportunity for selection as to form, color, and qualities in general.

In the course of the experiments a dozen or more of the most popular kinds of radish were used, the principal aim being to get the roots very uniform and smooth, all developing at the same time, instead of at different times as most radishes now do; and all of uniform color.

Another object was to develop varieties with the smallest amount of foliage that would be adequate to build up the roots quickly under good conditions.

I also gave attention at one time to the flavor of the radish, developing the sweet pungency for which the vegetable is relished.

As just noted, all the radish seed used in these experiments proved exceedingly variable; and even those that were selected and re-selected per-

A Universal Favorite

The carrot is a close competitor for position of first favorite among the root vegetables of the garden. Notwithstanding its popularity, however, it has not been given very great attention by the plant developer, and it does not vary greatly from the typical form here shown. It is worth experimenting with.

sistently for several years showed a tendency to reversion. But this variability, while it is annoying to the practical gardener, should give the radish added interest from the standpoint of the plant developer. The amateur who wishes to experiment with this species can begin with plants grown from any root or seed that he may secure. He might then hybridize these plants with seed of a Japanese or Chinese variety.

The radish is supposed to have originated in China and the vegetable is still very popular in the Orient, where besides being eaten raw it is pickled, dried, and preserved in various ways somewhat as we preserve fruits.

The Oriental Radish

The oriental radish is of large size and may be grown readily in a soil adapted to radishes in general; that is to say, a white, clean, sharp sand, which should be fertilized with chemical fertilizers only. The plants should have plenty of moisture and sunshine, thus being urged to rapid growth. They are much more subject to disease and liable to become pithy or hard when grown in rich soil than when grown in the sand, and are also of less satisfactory flavor.

There is little doubt that by crossing the oriental varieties with our common ones some interesting variations would be produced that

might lead to the development of new varieties not without importance.

Some Obstinate Root Bearers

In marked contrast with the members of the crucifer family, with their extraordinary tendency to variation, are the two familiar members of the garden family that are most prized for their roots, the carrot and the parsnip. For these have assumed a characteristic shape from which they show very little tendency to vary, and even under persistent cultivation have held very true to their type.

The plants are closely related, and both are descended from wild forms that are poisonous. Moreover the cultivated species themselves, if allowed to hold over until the second season, may develop a poisonous quality. But as ordinarily grown from the seed and pulled in their first season, they constitute wholesome vegetables of deserved popularity.

My work with the parsnip has been confined to the attempt to develop a race having roots that are smoother and of a broader or more compact form. But I found this a thankless task, as the roots tend to reach downward in spite of all the education that could be given them. It is a persistent quality that the plant seems very unwilling to give up. In this the parsnip shows its retention

A Bunch of Parsnips

Not even a tyro at gardening or botany needs be told that the parsnip is own cousin to the carrot. It is equally obvious, however, that the two belong to quite different species. Like its cousin, the parsnip has been rather neglected by the plant developer. Mr. Burbank has experimented with it to a certain extent, but the demand for the vegetable is not sufficient to justify his giving a great amount of time to it. Some one who cares to make the effort can no doubt improve it in a good many directions.

of the habit of its wild ancestor. The carrot also is not altogether free from its wild instincts, and will pretty readily revert to the wild state.

I have experimented with the wild carrot, which has a long, hard, slender root, and found that this could be brought back to the production of what might be called a civilized root.

I have also found that color can be added to the carrot root or taken away from it by selection through successive generations.

This is quite what we might expect when we consider the difference in color between the roots of the carrot and the parsnip, which in their wild forms are very closely related.

There is opportunity for some one to undertake the improvement of both parsnip and carrot as to the quality and shape of their roots, and such experiments might very likely prove successful if carried out persistently, notwithstanding my failure to produce marked modifications in this regard. The flavor of the carrot could also be improved, probably without great difficulty.

Salsify or Oyster Plant

There is another root that offers a challenge to the plant developer somewhat as do the parsnip and carrot, by the very fact of its obstinate resistance to any change. This is the plant called the Salsify, usually known to gardeners as the oyster-

plant or vegetable oyster. It is a biennial plant having long, slender, light-gray roots.

There is only one greatly improved horticultural variety. This is known as the Sandwich Island Mammoth. It is fully twice as large as the ordinary salsify, which it otherwise closely resembles.

I have worked with the Sandwich Island Mammoth with particular reference to improving the smoothness and plumpness of its root. But it was found to be one of the most stubbornly fixed of plants. This is quite what might be expected of a plant that has only one species under cultivation. We have elsewhere seen that the plants that have many species are the ones that tend to vary.

There are, however, two or three wild members of the tribe, one known as the Spanish salsify and another as the black salsify, a native of Europe. It is possible that these might be used to hybridize with the ordinary and the Sandwich Island species, and that the element of variability might thus be introduced.

Possibly through selective breeding, based on such hybridizations, new varieties of salsify might be developed and the plant might thus conceivably be made to occupy a much more important position than it does at present among garden vegetables.

Peas and Beans as Money Crops

Improvements Which Promise Much

A VERY good illustration of directive plant breeding is furnished by the case of the Empson peas.

This was a case in which I received an order for the development of a new variety of pea that would fulfill certain definite specifications, somewhat as a manufacturer of cloth or of electric dynamos or of machinery of any sort might receive an order for a new product to meet a special condition.

It is gratifying to record that I was able to meet the specifications, and "deliver the goods," as a manufacturer might say, about as accurately and satisfactorily as if the product had been one to be turned out by factory machinery instead of by selective breeding of a living plant.

The specifications were these: A variety that shall mature all its pods at the same time; bearing

individual peas of reduced but uniform size, sweet, and of superior flavor.

Here, it will be observed, there are several quite distinct characteristics to be borne in mind. Perhaps the most important, or at least the ones most difficult to attain and fix, were the uniform time of ripening and uniform size of the peas themselves. How these difficulties were met will be detailed presently.

First, however, let me tell just how it came about that the order for peas having just these specifications was received.

Manufacturer and Public

The order was given by a large canning factory, located originally in Colorado, but now having branch factories in other regions, with capacity to handle in the aggregate forty-six thousand cans of peas per hour.

The head of this company, Mr. J. H. Empson, is a man who has made a study of his public, and who aims to give the public what it wants. He discovered that there was a demand for canned peas of very small size. This had come about, probably, through the example set by the French, who can the peas when they are half grown, at which stage they appear to be sweeter than when more fully ripened.

The American public developed a liking for

Three Kinds of Burbank Peas

The story of these peas, and of some others, is told in detail in the text. It illustrates very vividly the possibility of making a particular type of vegetable-product to order. The "Little Ones" in the upper can represent one of Mr. Burbank's triumphs in this direction. The canners knew just what they wanted, and Mr. Burbank knew just how to get it for them by selective breeding.

these small peas, and a willingness to pay more for them than for the larger ones, but no American canner could duplicate them in size and quality.

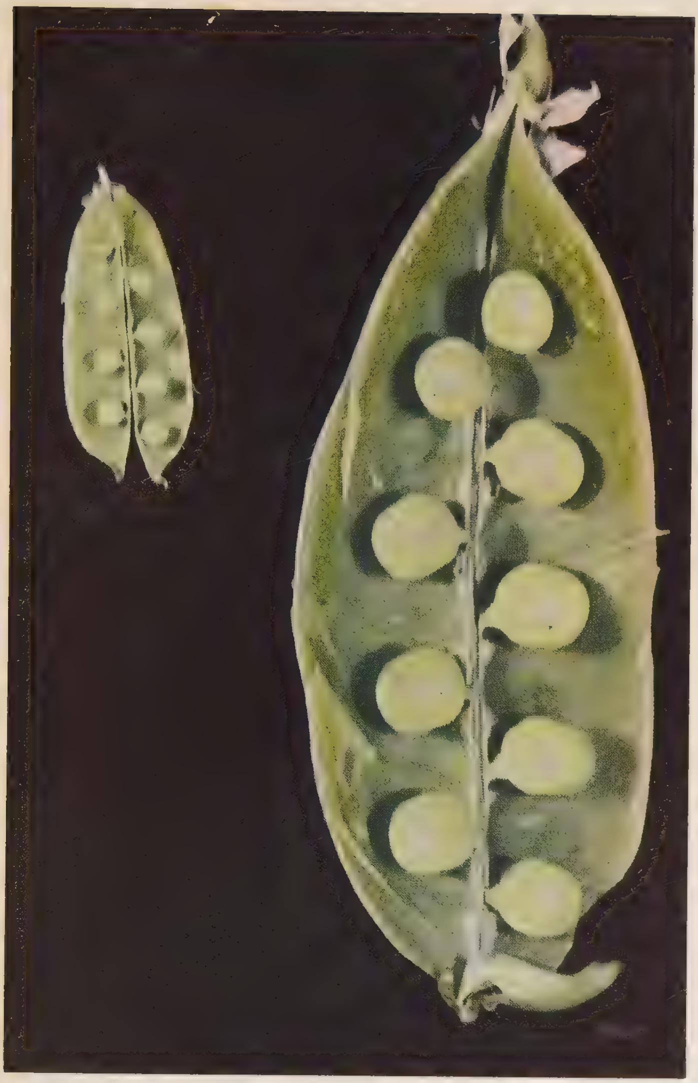
The American canners are themselves convinced that peas of medium size are really better; but they were desirous that the public should have what it wanted.

So it came about that I received a letter from the management of the canning company asking me to undertake the work of developing a pea that would meet the specifications as to size, and yet would mature in such quantities and with such uniformity that there would not be great loss in handling, as there would be if the pods matured at different times.

The reason that this specification is imperative is that peas for canning, according to modern methods, are not gathered by hand. Indeed they are not touched with the hand at any stage of their existence, even in planting. The crop must be ready all at once, because the vines themselves are harvested. A machine is drawn along the rows cutting off the roots about an inch underground, and raking four rows together in a windrow.

Cutting below the ground keeps the peas fresh and also ensures getting the entire crop.

A wagon immediately follows, gathering up the pod-laden vines like a load of hay, and hauling



Giant and Dwarf

These pods illustrate variation in peas of the same race. By selecting among the different plants grown from the same handful of seed, Mr. Burbank was able to make a dwarf variety, and at the same time to develop also several other varieties, including one or two very large ones, of quite different type. And progress was so rapid that the experiment was carried to a practical conclusion in three seasons.

them to the factory, where they are fed by machinery into a sheller, which consists of two big cylinders with vulcanized rubber cups on their surfaces, so arranged that the air pressure splits the pods open without crushing them.

The peas roll down an inclined plane with perforations of different sizes, and are thus automatically sorted into five grades, just as oranges of different sizes are sorted in California. The peas all fall into clean running water and are immediately canned without being touched. It may be interesting to add that a factory of this type has a record of putting canned peas on the shelves of the grocer within two hours of the time when they were growing on the vine in the field.

Peas in cans under these circumstances may be fresher than those purchased in the pod usually are.

These details as to canning obviously have no direct bearing on the methods of the plant developer. But they explain the specifications that were given along with the order for the new variety.

In attempting to meet the specifications, I followed the methods of rigid and systematic selection. There was no occasion for cross-fertilization, as the peas were of superior quality, and showed enough variation as to all of the desired characteristics to offer material for selection.

Peas in the Pod

Some such variation as this you may discover if you will search among the pods on different vines of the peas in your garden. If you will use the Burbank method of selection, as fully described in the text, and have sufficient patience, you may develop fixed races of peas along any of the lines suggested by these varying pods. Mr. Burbank has never developed peas that were "square so they will not roll off the knife," as a popular joke narrates; but he has developed lenticular peas, as well as round ones in great variety, and with widely varying characteristics.

My plan was to pick out in successive generations the vine that came nearest to meeting specifications as to number of pods, uniformity of ripening, and small size as well as uniform size of the peas themselves.

It was necessary, as in some other experiments of a similar kind, to watch the individual plants, selecting the very best individual plants, and harvesting them by themselves, counting the pods and counting the peas, and making careful record of results.

Fortunately it is possible with the pea to raise two crops in a season. Thus I was enabled to progress very much more rapidly than otherwise could have hoped to do. We could do two years' work in one.

So we were able to deal with six generations of peas in three years. And yet by that time the undesirable qualities had been so systematically excluded and desirable ones so persistently sought for that the educated pea vines fulfilled the specifications exactly.

I find in my files a letter bearing date of February 29, 1908, that may be quoted here as summarizing the results of the experiments:

"By express to-day," I wrote, "I send you all the peas raised from the *one best* of all my selections. This one is the one which produced the

most peas to the pod, the most pods to the vines, had the most uniformly filled pods, and in all respects was the most productive and best; on the whole, the best pea, taking quality, quantity, and everything into consideration, which I have ever seen. They are fifteen per cent smaller on the average. One other thing which I have added to them is that they are *sweeter* than the pea which you first sent me. They all came from *one single vine* which was the *best* in all respects and the seed has been reselected through six generations."

Multiplying the New Variety

Of course, the selected pea, as thus produced, existed only in small quantities. But it had been fixed as to type and could be depended on to breed absolutely true. It was necessary, however, for the company to multiply the seed for a number of years before there was enough of it in existence to use for the purposes of the canner. By growing the crops in California, however, where from two to four crops could be raised each year, and by using the entire product for the seed in successive years, the progeny of the single vine from which I developed the new variety had been multiplied by 1912 so that material enough was at last in hand to plant hundreds of acres and supply the cannery with the small, sweet, uniform-sized and uniform-ripening pea that was desired.

Showing Variation in Beans

The bean is even more variable than its cousin the pea; and there are a good many species under cultivation, so there is almost endless opportunity for developing new varieties. Here are some samples that suggest the possibility of easy and interesting experiments.

I have cited this case in detail, not because it is of exceptional importance in comparison with other of my plant developing experiments, but simply because it illustrates the possibility of developing quite rapidly a particular plant to meet a specific commercial need.

But to understand fully the conditions met even in this single experiment, it is necessary to add that I did not confine attention to the production of the single variety just described, even in the line of experiments that were undertaken specifically for the purpose of producing that variety. On the contrary, while scrutinizing the vines for small peas of uniform size, I kept vigilant watch also for other vines that varied in the opposite direction.

Peas Modified in Other Directions

By carrying forward several series of selections at the same time, a number of varieties were simultaneously developed that differed widely both from one another and from the original stock.

I found, for example, in the observation of the early generations grown from the seed, that some plants would produce four or even five times as much as others. This habit of productiveness was carried to the next generation with a good deal of certainty. So it proved possible, by careful selection, in three years, to develop new forms of peas

which produced regularly four and five times as much as the average production of the parent form.

Of course, this quality of productivity was combined with the various other qualities and was manifested in the perfected pea that was delivered along with the letter just quoted.

But there were other qualities which obviously could not enter into the combination, because of variation in exactly the opposite direction from the one in which we were developing the little canning pea. Thus, for example, one variety instead of having small peas had exceptionally large ones. Another varicty produced lozenge-shaped peas. These seemed to be unusually sweet, and as they were also among the most productive, I made two strains of this selection alone. One of these is a very large lozenge-shaped pea, circular, and indented on the flattened sides.

Both are practically fixed, coming true to type from seed.

In point of fact, by having different ideals and bearing them in mind all along, I developed four strains of new varieties that the canners were glad to purchase, in addition to the one that they had specifically ordered. And all this was done, as just noted, by selection, without the aid of hybridizing experiments.

A Burbank Perennial Bean

Mr. Burbank began experimenting with beans when he was a mere boy. At that time, back in Massachusetts, he hybridized different species, and produced some quite extraordinary results. In recent years he has taken up the work again, attacking it with undiminished zeal. The picture represents one of his present-day successes.

It should be explained that the pea is normally self-fertilized, so that there is the closest inbreeding, and it is therefore relatively easy to fix a type. Moreover the pea is a very pliable plant, producing new varieties with little care and labor as compared with many other plants. Although I have devoted much less time to it than to many other plants, I have developed numerous varieties that are specially modified for color, for productiveness, for size, for quality, or for resistance to mildew and other affections. And other experiments are under way that will probably lead to still further developments.

Mendel's Famous Experiments

Although much may thus be accomplished with the pea by mere selection, it should be remembered that this plant offers exceptional opportunities also for development by hybridization. In particular it should be recalled that the extraordinary experiments through which the Austrian monk, Mendel, made the discoveries that have created such commotion in the biological world, were made with the common garden pea.

Reference to these experiments has been made more than once, but it will be worth while to examine them a little more in detail in the present connection.

The discovery that Mendel first made, to which

Burbank Lima Beans

Mr. Burbank says that the bean, notwithstanding its popularity, has been somewhat neglected. Perhaps it would have been more coddled and developed if it had been less hardy. But beans grow anywhere, and under any conditions, and so do not seem to demand attention. Nevertheless they reward the experimenter by their responsiveness, as these giant limas, developed under Mr. Burbank's tutelage, clearly testify.

we have already referred, was that certain qualities of the pea are grouped into very conspicuous pairs.

His investigation led him to believe that there are at least seven differentiating characters that could be relied upon to reproduce themselves with certainty in the offspring of the pea. These characters, which he came to speak of as "unit" characters, are the following:

(1) The form of the ripe seed, which may be roundish, either with or without shallow wrinkles, or angular and deeply wrinkled.

(2) The color of the reserve material in the cotyledons or little leaves that first appear when the seedling comes out of the ground; the colors being pale yellow, bright yellow, orange, or green.

(3) The color of the seed coats; white, as is usual in peas with white flowers, or gray, gray-brown, leather-brown, with or without violet spots, etc.

(4) The form of the ripe pods, whether inflated or constricted or wrinkled.

(5) The color of the unripe pods, whether light or dark green or vividly yellow, these colors being correlated with colors of stalk, leaf, vines, and blossoms.

(6) The position of the flowers, whether axillary or terminal.

(7) The length of the stem of the plant itself, whether tall or dwarfish.

It is obvious that in each case the different qualities named are antagonistic or mutually exclusive. The seed cannot be at the same time round and angular; it cannot be at the same time smooth and wrinkled; cotyledons cannot be at once yellow and green; the pods cannot be at once inflated and constricted. And as each race of peas, when inbred, holds true to its type, there was opportunity to observe the effects of crossing the different races in relation to these different fixed characters.

The results Mendel obtained have already been outlined, and more than once referred to in this and in previous volumes.

It will be recalled that, as regards the various pairs of antagonistic characters, he found that one or the other proved prepotent or dominant in the first generation; but that in the second generation (when the first generation hybrids were inbred) the submerged or recessive character would reappear in one case in four on the average. Thus he found that in the pea tallness of stalk is dominant to shortness of stalk; that yellowness of seed is dominant to greenness of seed, etc.

This was demonstrated by the fact when a tall pea was crossed with a short one all the offspring

A Stripling from the Tropics

In the foreground, the South American bean whose stalk suggests the one that Jack grew, according to the nursery legend. To appreciate the size of this tropical bean, growing now in Mr. Burbank's garden, it should be explained that the corn in the experimental bed beside it is more than eighteen feet tall.

were tall, but one-fourth of the offspring of the second generation were short.

Similarly when a pea with yellow pods was crossed with one having green pods, all the plants of the first generation had yellow pods; but one-fourth of their offspring of the next generation had green pods.

The Segregation of Characters

A second very important feature discovered by Mendel was that the different antagonistic pairs of qualities are transmitted quite independently of one another.

For example, the relations of tall and short peas, blended in heredity, are quite independent of the question of yellowness versus greenness of pod. So observation may be made as to two or more qualities in the course of the same experiment.

Thus if a tall variety of pea that bears green pods is crossed with a short variety bearing yellow pods, all the offspring will be tall peas with yellow pods—therefore unlike either parent. But the offspring of the next generation will show a recurrence of each of the recessive factors in one case in four, so that one-fourth of them will be short and one-fourth will have green pods. But it appeared, so far as Mendel could determine, to be a mere matter of chance—like the throwing of

dice—as to the exact number of cases in which shortness of stalk would be combined with the bearing of yellow pods.

Pairing the Factors

If we assume—as Mendel finally came to do—that each of the different qualities about which we are speaking is represented in the germ plasm by a definite mechanical factor which must be paired with another factor, either like or unlike itself, in order to stimulate the development of the character it represents, then at least a provisional explanation of the observed facts might be found in supposing that a dominant factor when mated with a recessive one hides or obscures the recessive one in that particular combination; but does not eliminate it.

And when the factors are again mixed to produce a new generation, they are still equal in number, and if we think of the factors as tangible things—let us say like black or white checker men—it will appear that if equal numbers of each are mixed together and taken from a bag in pairs at random or blindfold, it will come about, according to the mere theory of chances, that one time in four two of the white checkers will be paired.

This accounts in a crude and mechanical but on the whole a rather satisfactory way for the appearance of the recessive character—say short-

Giant Horse Beans

This is a variety of horse beans improved by Mr. Burbank through selection, and now growing en masse in his experiment gardens in Santa Rosa. The horse bean is frequently used as a cover crop, and the value of this perfected variety for such a purpose is well illustrated in the photograph.

ness of vine or greenness of pod—in one individual out of four of the second-generation progeny.

And when we apply the same reasoning to the case where two pairs of factors are under consideration—tallness versus shortness, and yellowness versus greenness in the present case—it appears that each pair of factors will follow precisely the same law, so that one in four of the second generation descendants will be short and one in four will be green; but that the same law of chances, applied to this more complex case, gives us only one case in sixteen in which two factors for shortness are combined with two factors for greenness in the same group.

In other words, one pea in sixteen descended in the second generation from the tall pea with green pods and the short pea with yellow pods will have a short vine and at the same time will bear green pods.

This will be a new variety. It has no new quality, but it has the old qualities in a new combination.

Extending the experiment one stage further, Mendel found that the second-generation peas that show the recurrence of the recessive factor will breed true to that factor. And this, again, is quite what might be expected on the theory just outlined. For the pea that contains two factors for

Roots of the Mammoth Soy Bean

This picture shows the nodules due to the nitrifying bacilli, through which the leguminous plants are enabled to perform a feat that other plants find impossible,—namely the direct extraction of nitrogen from the air. Other plants might starve for want of nitrogen, although bathed in the atmospheric ocean which is so largely composed of nitrogen. But the legumes, thanks to the particular types of bacilli that colonize the roots, can get a supply, or a partial supply, of nitrogen, without waiting for it to be combined and made into soluble compounds. Nowadays cultures of the nitrifying bacilli are sometimes thrown on a field, as one sows grain or the innoculated seed, put out under the trade name "Nitragin", is sown.

shortness will obviously have no propensity to grow tall, and the pea that contains two factors for greenness of pod will obviously have no capacity for the production of pods other than green.

So our short pea vine with its green pods, although it represents a new variety, which, for the sake of argument we assume never to have existed before; and although it appeared suddenly as what might be considered a mutation, yet is fixed from the outset, and will breed true, and constitute an established variety.

All this we have referred to in earlier chapters, and we have seen many illustrations of this so-called Mendelian inheritance in the case of a good many of our plant developments—the white blackberry, for example, the stoneless plum, and the thornless blackberry among others. But it seemed worth while to make specific reference to Mendel's work with the peas, in the present connection, in particular because this work doubtless represents the most important thing that has been done with the pea at any recent stage of its development.

Peas Versus Beans

It was perhaps fortunate that the Austrian monk chose the pea for his investigation rather than the bean, for, notwithstanding the fairly close relationship between these two, there is a rather marked difference between them as to their prac-

tical response to the efforts of the plant developer. Perhaps because the pea has been cultivated under varied conditions, and selected for a wide variety of qualities, this plant shows a marked tendency to vary, suggesting in this regard the evening primrose and the godetia, and the new varieties are often practically fixed from the outset.

With beans it is less easy to trace and classify the opposing "unit" characters, and in practice it is often necessary to select rigidly and continuously for five or six successive generations in order to fix a new variety.

An illustration of the complexities that may result when beans of different kinds are crossed was given me at the outset of my work as a plant developer.

Crossing the Pole Beans

Almost my first experiment in hybridizing was made by crossing the horticultural pole-bean or wren's egg with another variety of pole-bean known as the red cranberry bean.

The hybridization was effected with some difficulty, inasmuch as only one blossom in perhaps fifty responded to cross-pollenization and a part of the offspring seemed to lack vitality, as I succeeded in bringing but one plant to maturity. But this was in some respects the most astonishing bean plant that I have ever seen. It bore long

Cow Peas Under Cultivation

This picture shows another form of leguminous plant that has become popular in comparatively recent years. It is of solid and compact growth, and makes a remarkable cover or forage crop. Like the other legumes, its product is rich in nitrogen, a fact long recognized but the explanation of which has been given only in comparatively recent years.

black pods and the beans within them were as black as ink.

Yet one of the parent beans had produced a crimson pod with a red seed, and the other a crimson and white striped pod, with red and white striped seed.

Here, it will be seen, there was no such sharp differentiation of the color-factors for pod or seed into opposing pairs, with dominance in one and recessiveness in the other, as was shown by the peas in Mendel's experiments. On the contrary, the union of red beans with red and white striped ones produced something totally unlike either—namely, a jet black bean.

But in the succeeding generation the offspring of the black bean showed a breaking up into new groups of characters suggestive of Mendelian heredity. Some of them were black, some red, some speckled, and some white. There were corresponding variations also as to size and shape of the beans, some being large and some small, some round and some flat. And there was marked diversity in time of ripening.

As to the vines themselves, the original hybrid showed the enhanced vitality that commonly characterizes the offspring of rather widely separated parents. The original first-generation vine (which bore the black beans) grew enormous, outstripping

either parent by eight or ten feet, and rivaling the growth of a hop vine. The vines of the second generation were as diversified as the seed.

Some of them were long and vigorous, while others were extraordinarily dwarfed, some being so stocky as to grow pods that almost immediately touched the ground and were obliged to bend back like hairpins to find room for growth. There were corresponding variations in size, shape, and color of the leaves.

All this suggests that the beans originally hybridized were themselves of very mixed ancestry, and that a large number of hereditary traits that had been blended in them were permitted to make themselves manifest through the recombination and segregation of hereditary factors.

The reader cannot fail to note a similarity here between the results obtained and those that were obtained when the Persian walnut and the California black walnut were hybridized. There, as in the case of the beans, the immediate offspring were of gigantic growth, but their progeny in turn showed both giants and dwarfs.

The interest of both cases (and of a number of other allied ones that will be recalled) in illustrating the Mendelian principle of the segregation of recessive factors for size, leading to the production of a race of dwarfs, will be obvious.

Soy Beans

Yet another legume that is extraordinarily vigorous and prolific. Like the others, it develops nodules on its roots, under influence of a particular type of nitrifying bacillus, and so takes up nitrogen from the air, whereas other plants are obliged to depend upon soluble nitrogen compounds which are relatively rare. The value of such a crop as this in restoring nitrogen to the soil is inestimable.

Another hybridizing experiment with the beans, also undertaken in the early day of my investigations, brought together two varieties that are even more distantly related.

Crossing Pole Beans and Limas

In this experiment I hybridized the horticultural pole-bean, or "wren's egg," with the lima bean. It proved exceedingly difficult to make this cross, but after many fruitless efforts I at last succeeded in securing a single pod containing four sound beans by using the pollen of the lima on the pistil of the horticultural bean.

When these beans were planted, in the summer of 1872, a very strange result was observed—the beans themselves had in all respects the form, size, and appearance of the horticultural bean, but when their sprouts broke ground it was at once observed that the upper part of their cotyledons (varying from one-quarter to three-quarters of their length in different specimens) were indubitably those of the lima bean; while the lower part of each cotyledon was precisely that of the horticultural pole-bean.

These parts were connected with serrated edges, which at last separated, allowing the lima bean part to drop away. Such separation, however, did not occur until the vines had made a foot or more of growth.

The cotyledons on each side were divided uniformly in every case.

Thus the influence of the pollenizing parent was very markedly shown in the young vines from the moment of their appearance. But after the cotyledons had fallen, all evidence of the paternal parentage of the plants disappeared. The vines did, indeed, show unusual vigor throughout the season, this, of course, suggesting their hybridity. But as to appearance and characteristics in general, with this exception, they were essentially horticultural pole-beans like their maternal parent.

The experiment was carried on for several succeeding generations, but the progeny showed no reversion to the traits of the lima bean. The characteristics of the pole-bean had seemingly been prepotent or dominant to an overwhelming degree.

This, then, would appear to be another case in which a new race was formed in a single generation by the mingling of two widely divergent racial strains. These hybrids of the lima and the pole-bean may be compared, in that regard, to the Plumcot and the Primus berry, to name only two of the various allied instances that have come to our attention. This is what I call a seed-graft-hybrid. This and one other instance elsewhere described are the only two similar ones that ever

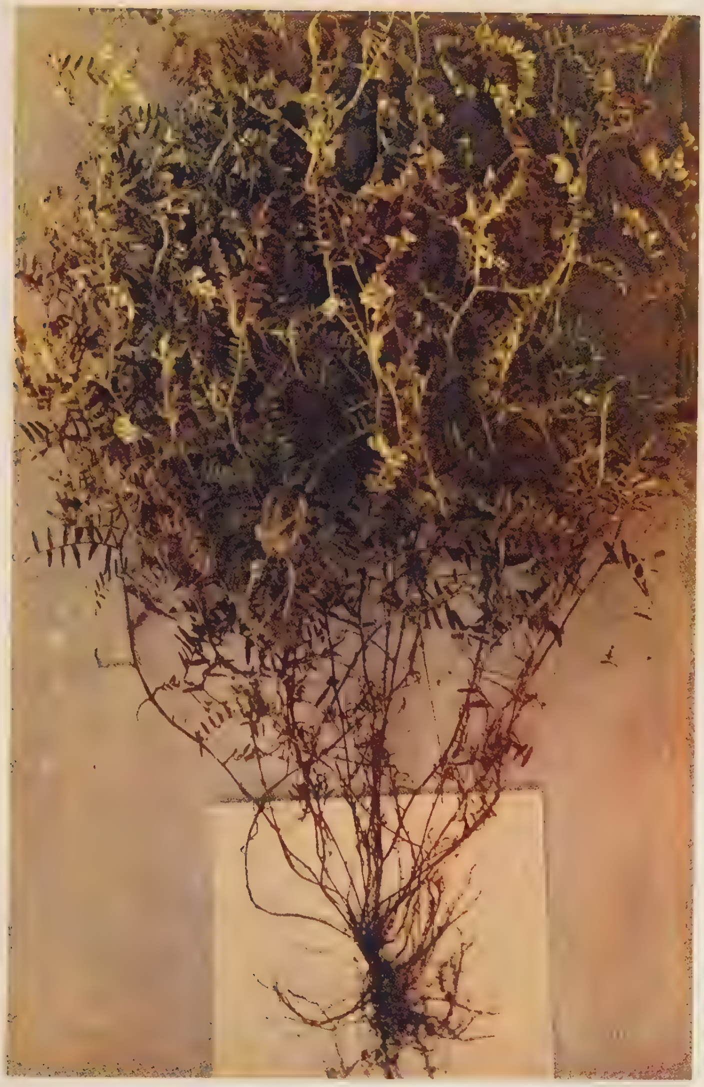
came under my observation, and they never, so far as I know, have been duplicated before or since.

But the fact that the lima bean, the conspicuous traits of which were submerged and subordinated in the mature hybrid, should have made its influence strongly felt in the seedling at the beginning of its growth is peculiarly interesting.

One recalls the similar case of the raspberry plant hybridized with pollen from the strawberry. In that case, the young hybrids at first bore close resemblance to the strawberry plant, yet subsequently shot up into the air and took on the aspects of the raspberry vine. In both cases, then, the influence of the seed plant was at first submerged but ultimately preponderant.

We cannot be sure, however, that this was more than a coincidence. To determine that point it would be necessary to make a reciprocal cross.

It has been pointed out that as a rule it appears to make no difference in the ultimate character of the hybrid as to which of its parents is the staminate and which the pistillate one. Yet the cases of animal heredity in which there is a marked tendency to cross-inheritance — from father to daughter and from mother to son—suggests that there may be analogous cases in plant life. In any event, the analogy between the hybrid



A Hairy Vetch

Here a leguminous plant, cousin to the peas and beans, is shown with both top and root, to illustrate the luxuriant growth of the foliage, and the nodules on the roots that enable the plant, thanks to the nitrifying bacilli that inhabit them, to take up a supply of nitrogen from the air. These plants may have the most luxuriant foliage, even when growing on leached and barren soil, that will scarcely support other types of vegetation.

beans and the hybrid strawberry-raspberry, each following first the staminate and then the pistillate parent, is not without interest.

Opportunities for Further Experiment

After an interval of many years, during which I did not experiment further with the bean, I have somewhat recently found time to turn attention again to this very interesting plant, and have developed a large number of new varieties of unusual qualities.

The recent experiments have had to do with the bush bean, and I have paid attention to a large number of attributes, including form of the plant, color of bean, and the quality and flavor. The new experiments have involved the crossing of many varieties and have brought to light many interesting developments, although none perhaps as striking as those just outlined.

I have found that it is feasible to segregate and recombine the traits of different varieties of beans in almost any desired combination. Thus, for example, it is perfectly feasible to put the pod of one bean on the vine of another, quite as Mendel did with his peas. Observation will show what qualities or characteristics are prepotent or dominant even without directive effort on the part of the plant experimenter.

It will be observed that in the second, third, and

fourth generation plants will appear that show the pods and beans of one of the original parents combined with the leaves and vine of the other, in all possible combinations.

As I have operated with about forty varieties of beans in the course of these experiments, it will readily be surmised that the number of new combinations that have been presented is almost infinite. Among the hybrid stock can be found beans of almost every color and combination of colors, black, brown, blue, slate, yellow, green, and white; mottled, striped, and otherwise variously marked and shaded. Moreover, if beans of one color are selected and planted, as a rule all the other colors appear in the progeny.

One finds the offspring bearing beans that are speckled, spotted, striped, and shaded in every conceivable way.

Yet beans that show this diversity of color may be quite uniform as to size of the beans and time of ripening, as well as in regard to the size and general appearance of the plants on which they grow.

In other words, a certain number of characters may have become fixed while other characters are still variable. And here the obvious explanation is supplied, at least provisionally, by the supposition that the plants in question are unmixed as to

their Mendelian factors for size and character of vine, but retain mixed factors for color of seed.

No one as yet, however, has worked out in detail the combinations of hereditary factors for the bean as Mendel worked it out in the case of the pea. Such an investigation would constitute one of the most interesting experiments in plant breeding that any one who has time for it could undertake. It is true that the hybridizing of the plant of this genus is rather difficult, inasmuch as the flowers must be opened and the stamens removed with a pair of small forceps to avoid self-fertilization.

But, on the other hand, once cross-fertilization has been effected there are obvious advantages in later generations in working with a plant that is normally self-fertilized, the pollen of which is inaccessible to insects.

All in all, I think the bean offers as many inducements for improvement as any other plant under cultivation.

—Although much has been and may be accomplished with peas and beans by mere selection, these plants offer exceptional opportunities also for improvement through hybridization.

The Tomato—and an Interesting Experiment

A Plant Which Bore Potatoes Below and Tomatoes Above

A VISITING scientist who had seen my little preserving tomato and had learned its origin was curious to know just how I came to make the hybridizing experiment that resulted in its production.

I found it difficult to answer the inquiry to his entire satisfaction. One does not recall all the details as to methods, let alone motives, after an interval of twenty-five years. But so far as can be recalled, I had no very definite object in combining the common tomato and the currant tomato except the one of general interest in the processes of nature, and a sort of all-inclusive desire to see what would happen when plants of such diverse character were united.

My visitor felt that I must have had some definite idea in mind—some ideal tomato at the production of which I was aiming, and he seemed to

feel distinctly dissatisfied when assured that in this particular case a result had been achieved that had not been forecast. The plant developer had been like a chemist putting together newly discovered elements. He knew that he would probably get something interesting, but just what that something was to be could not be predetermined.

Two Types of Inventions

I recall this incident by way of illustrating another phase of the plant developer's art than that illustrated by the development of the canning pea as detailed in the preceding chapter. In that case, it will be recalled, the plant developer was in the position of an inventor called upon to meet a precise set of specifications. He knew from the outset what was to be aimed at and, having acquired a certain craftsmanship, he knew how to set about securing it.

A large number of inventions in the mechanical world have such an origin as this.

When Edison started out to find a filament that would show just the right resistance to the electric current, and yet would not be consumed with its own heat, he knew just what he was seeking, and his problem of the development of an incandescent light bulb was comparable, in a general way, to the problem of producing a canning pea of just the right size and quality.

But, on the other hand, a long list might be cited of inventions and discoveries of vast importance that were matters of accident. Perkins' discovery of the aniline dye; Nobel's discovery of nitro-glycerine; Röntgen's discovery of the X-ray; Becquerel's discovery of radio activity—these are instances where a man found something for which he was not specifically looking. Of course he had to be in line of discovery. It was essential that he should be handling the right materials, and working in a laboratory having the right accessories, or the discovery could not have been made. Nevertheless, in each case, the discoverer found something for which he was not seeking; his experiment had results that he could not have predetermined.

And here again, the analogy with that other type of experimentation through which, for example, the preserving tomato was developed will be obvious.

Looking for Surprises

The point to be emphasized is that the plant developer is an inventor who works sometimes according to one method and sometimes according to another. He is dealing always with complex and intricate matters. Sometimes he has studied them so well that he knows what to expect of them in certain combinations. In other cases he is feel-

ing his way, and has no very clear notion of what to expect.

It might be said that he is looking for surprises rather than for anything definite; and in that event he is pretty sure to find what he is looking for.

Such at least was my experience in the early experiments with the tomato that led ultimately to the production of the particular hybrid at the moment under discussion. These experiments had their origin at the very beginning of the period of my investigations in the field of plant development, a good while before I came to California.

But in those days, notwithstanding one or two successes, I was only laying the foundation for my future work—learning how to handle the tools of my trade. So although there may have been interesting discoveries within reach, I did not always know how to grasp them.

I had not learned, for example, the all-important lesson that the second-generation hybrid, rather than that of the first generation, is the one that must be looked to, in a large number of cases, for important development.

The Story of a Fruit-Like Tomato

But when I came to California and found opportunity for expanding the work, I from time to time took up the old New England experiments where they had been left.

The Burbank Tomato

Mr. Burbank has done some very remarkable work with the tomato, as we have learned in an earlier volume, and as will be illustrated in other pictures. This picture shows one of his finest tomato products, which has been thought worthy of introduction under his name. As to symmetry of form, smoothness of skin, and attractiveness of color, it speaks for itself. Its qualities of flesh correspond.

In some cases I had brought seeds with me, and was able to complete under the new conditions experiments that had been begun in New England. In other cases it was necessary to start anew, but I had experience as a guide, and that constituted an asset that often proved a wonderful time saver.

In the case of the tomato, experimentation was reopened on a comprehensive scale about the year 1887. It was at this time that I hybridized the common potato and the currant tomato and produced the interesting new form about which we have just spoken. The common tomato needs no description, but the currant tomato is much less familiarly known. It is a plant with long, slender, trailing vines and slender leaves and it bears racemos of small currant-like fruit. It occurred to me that it would be highly interesting to hybridize this trailing plant with a particularly tall, upright, compact variety of the common tomato.

The cross was made reciprocally, pollen from each plant being used to fertilize the stigma of the other.

The fertilization was effected without difficulty, and an abundant supply of seed was produced. The hybrids that grew in the next generation were many of them pretty clearly intermediate in form and appearance between the parents. But some of them were almost ludicrous in appearance.

They took on twisted and contorted forms, and in particular their leaves were curled and twisted into fantastic shapes.

As to fruit, some of the plants produced long clusters with tomatoes much larger than cherries; others furnished small fruit like that of one of the parents. And in some cases a plant that had retained the short stocky tree form of the common tomato bore clusters of small tomatoes in bunches similar to those of the other parent.

The foliage varied astonishingly between the two types. In some there was an exact compromise that was very curious. The dark, blistered leaves of the ordinary tomato, combined with the long, slender leaves of the currant tomato, produced a most interesting effect. Other specimens showed every possible gradation between the parent forms.

Here, then, was a case in which there was no conspicuous dominance of one parent or the other as regards any individual character that could be segregated and classified.

Neither as to size and form of plant-stalk, nor as to leaf, nor as to the fruit itself, was there clear prepotency or dominance of one parent over the other.

If there was an exception to this it was perhaps that the fruit tended to be borne in clusters, as in

Vigor Through Crossbreeding

At the left a hybrid tomato which has altogether outstripped a representative of one of its parental forms, shown at the right. Similar illustrations of the extraordinary vigor that hybrid plants sometimes take on has been shown in earlier volumes. The contrast here, however, is peculiarly striking. Here the giant seedling is probably only mimicking some equally gigantic ancestor, as we should learn could we trace its full pedigree.

the case of the currant tomato, rather than singly or in small groups as with the ordinary tomato.

Attention is called to these diversities because it is well to emphasize anew that the phenomena of the clear segregation of "unit" characters, with the exhibition of dominance and recessiveness—which the pea with which Mendel experimented manifests so beautifully, and which we have seen manifested in the characteristics of numerous other plants—is not a universal phenomenon that the plant experimenter may confidently expect always to discover and use as an easy and simple guide along the path of plant development. Different species of plants, different varieties, even different individuals show diversity as to the extent to which the so-called unit characters are segregated and mutually combined or antagonized, as the reader who has followed the story of various plant developments already outlined is clearly aware.

We shall have occasion to revert to this subject more than once, and to point out various possible interpretations of the phenomena, various underlying harmonies that do not appear on the surface. But for the moment we are concerned with the story of the new tomato, and may be content to put forward the facts regarding it without great insistance on their theoretical interpretation.

Suffice it that the progeny of the tree-like tomato and the trailing one were a varied company, giving the plant developer almost endless opportunities for selection.

I chose, naturally, from among them those that bore the handsomest and largest fruit, and in planting these, was enabled, in the course of several generations, to secure a very handsome plant with attractive fruit of new type which came true from seed. It required about six years to produce and make sure of the new variety, which was announced in my first catalog of new plants, issued in 1893. The description there given of the new fruit was as follows:

An Interesting Hybrid

"This distinct novelty and ornamental fruiting plant grows about twelve inches high by fifteen inches across.

"The curious plated, twisted, and blistered, but handsome leaves, sturdy, compact growth, and odd clusters of fruit will make it a favorite ornamental plant."

Another account supplemented this by describing the fruit as "a small, round, scarlet tomato, borne in clusters, the individual fruits measuring only three quarters of an inch in diameter; of splendid scarlet coloring and unusually rich, sweet flavor."

Fruits of a Tomato Hybrid

These interesting cherry-like tomatoes were the products of an early experiment by Mr. Burbank, in which the so-called currant-tomato was crossed with an ordinary upright variety. The result is a fruit that is not only very novel from the standpoint of ordinary tomato traditions, but distinctly attractive from a gastronomic standpoint.

The comparatively rapid development of this curious form of plant, so widely divergent from the ordinary tomato, illustrates the possibilities and suggests the compelling interest of such experiments in hybridizing and selecting even our commonest garden plants.

The work is of course no different in principle from that followed by the plant developer in the orchard, whose work has been detailed in earlier volumes. But there is this important practical difference: In experimenting with such a plant as the tomato, we get results quickly because the plant grows and fruits in a single season. The results of any given experiment may be known within a few months of the time when the seed is planted. This is quite different from the case of the orchard trees, which require, as we have seen, long periods of patient waiting, few of them bearing, even under forced methods of grafting, in less than two or three years, and some of them, such as the pear and fig, requiring a much longer period.

On the other hand, there is one regard in which the orchardist has an advantage. It is not necessary for him to fix his new varieties so that they will come true from the seed, inasmuch as his plants will propagate by division. But in dealing with plants of annual growth, like the tomato, it is obvious that a new variety can have little value

unless it will come true from the seed. (The tomato is really a perennial, that is treated as an annual.)

So the task is not completed when a new variety is produced; additional experiments must be conducted to *fix* the variety. Even this may be accomplished, however, by careful attention to selection, in the course of a few years, as we have just seen illustrated in the case of the hybrid tomato.

Nineteen-Year-Old Seed

Among my later experiments with the tomato were some that had exceptional interest because of the material used.

It chanced that when I left home in the east, many years before, I brought with me seed of several of the standard varieties of plants and of some crossbreed varieties; and, as has been pointed out, I was hybridizing tomatoes as well as beans and other plants even at that time.

The lot of seed thus brought to California included some seeds of the tomato. As was customary in those days, this seed had simply been pressed out of the fruit, and dried on a piece of paper with the surrounding pulp still clinging to it.

Nineteen years afterward I planted some of these seeds, being interested to see whether they retained their power of germination. Somewhat

Another Interesting Hybrid

This picture shows foliage as well as fruit of another type of tomato hybrid. The tomato is a comparatively recent acquisition in the vegetable garden, and its possibilities of variation through hybridization and selection have by no means been exhausted. It is a hardy, thrifty plant, vigorous of growth and prolific, with which any amateur may experiment to his heart's content; and it is almost sure to repay the effort expended upon it.

to my surprise, almost every seed germinated. But the majority of the seeds did nothing more than form cotyledons, lacking the central bud for further development. There were a few exceptional plants, however, among the large company—perhaps altogether two dozen—that continued their growth and in due course fruited.

The fruit of some of these plants grown from nineteen-year-old seed was sent to an eastern horticultural journal, whose editor commented on the fact that seed kept for this long period still produced fruit quite equal to anything that had been developed in the intervening nineteen years.

In planting the nineteen-year-old seed, I retained a certain quantity from the same lot for a further test. The following year it was planted in the same careful manner. But although a few of the seeds germinated and sent up cotyledons of a weaker type, not one had the power of developing beyond that stage.

All of these seeds in the tewntieth year seemed to have lost the capacity to produce a central bud from which the plant stem could develop.

Of course it may have been only an accident that a few seeds were able to take on mature growth after nineteen years, whereas not one could do so after twenty years. But I am inclined to think that the seeds had reached just about their

limit of suspended vitality. The fact that germination began, but that it did not continue because of lack of a central bud, suggests that degeneration of part of the substance of the seed had taken place. Seemingly it was only the most resistent seeds that were able to stand this degenerative process, and retain unimpaired vitality to the end of the nineteenth year. The heredity of those that grew was preserved intact: the seeds producing exactly such plants and fruit as if they had been planted nineteen years before.

The Vitality of Seeds

The interesting question arises as to whether the degeneration of germinal matter was confined entirely to the store of nutrient substance in which the germinating nuclei of the future plant are imbedded, or whether it included any portion of the germinating structure itself.

The fact that failure to continue growth—in the case of the seeds that put forth cotyledons and then died—was due to a lack of the central bud that usually puts forth between the cotyledons, suggests that the germinal substance itself was impaired. Of course this germinal matter is of tangible, even if very minute, size and there is no apparent reason why it might not be impaired as to a portion of its substance.

Conceivably, the substance of the complex

VII-41

Tomato Leaf Variation

These leaves from hybrids of a blending of different tomatoes are peculiarly interesting, both because of their wide range of variation, and because of the similarity of some of them to the leaves of the potato, a cousin of the tomato, with which it has many points of ffinity.

molecules making up the germinal protoplasm may undergo a gradual process of decay or disintegration through the throwing out of some of their atoms, somewhat as radium and its allied substances are disintegrated. This of course is a pure assumption, yet it is not altogether without plausibility.

But whatever the precise manner in which the degeneration of the germinal plasm is brought about, the suggestion that one portion of its structure may be affected more than another raises a question as to whether, conceivably, such a deterioration of the germ plasm within a seed, in an exceptional instance where a seed is stored for a number of years before being placed under conditions proper for its germination, might not result in the production of a deformed or modified plant.

Whatever differences of opinion may be held among biologists as to the possible transmission of modifications of the body plasm, all are agreed that modifications of the germ plasm become a permanent heritage and are passed on to the offspring. So it seems at least a possibility that we have presented, in the deterioration of the germ plasm within the seed, an explanation of the appearance of mutants or sports that may become the progenitors of new races.

Attempts to produce mutants by treating the

ovules of plants with chemicals, including radium, have been made by several experimental botanists, notably by Dr. D. T. MacDougal, of the Desert Laboratory at Tucson, Arizona, and by Prof. C. S. Gager. Prof. MacDougal's evening primroses, grown from seeds that were treated with chemicals while in embryo, sometimes differ markedly from other plants of the species.

Prof. T. H. Morgan has made similar experiments with the eggs of a fly, treating them with radium, and thus producing individuals strikingly different from their parents.

These experiments, then, although they mark merely the beginning of a new line of research, are interesting in their suggestiveness. And it occurs to me that the case of the nineteen-year-old tomato seeds may have a bearing on the same subject.

It would be well worth while to conduct a systematic line of experiments in which seed of a fixed species is stored in large quantity, and a certain proportion planted each year, careful record being made of the characteristics of the successive groups of plants, with an eye to any modifications that may occur when the seed approaches the limit of the term through which it can maintain vitality under the conditions given it.

It is said that there are records of wheat

Collected for Seed

These tomato vines, with their undeveloped fruit, were collected for seed before the fruit ripened, to guard against loss, as the experiment was one to which a great deal of attention had been given, and which promised excellent results. The description in the text of Mr. Burbank's experiments with tomato seeds that he had brought with him years before from Massachusetts, is worth consulting.

germinating after it had been preserved for centuries in the tombs of Egypt, although there is no proof of this; but most seeds have far more restricted capacities for maintaining vitality. My experiment suggests about twenty years as the limit for the tomato seed under fairly good conditions. So the seeds of some fixed type of tomato might very well be among those selected for such an experiment as that just suggested.

My own observations in the matter are chiefly confined to what has just been related to my nineteen and twenty-year-old tomato seeds; and I must leave further investigation along this line to younger experimenters.

Grafting Tomato and Potato

Doubtless among my most interesting experiments (to the general public) with the tomato have been those in which this plant was grafted on the stalk of the potato; together with the complementary experiments in which the potato was grafted on the stalk of the tomato.

The grafting of herbaceous plants such as these presents no complications as a mechanical procedure. The fact that the stem is succulent throughout makes such grafting a less delicate process than the grafting of twigs of trees, for example, in which, as we know, it is necessary to bring the cambium layers of the bark in accurate

contact. With herbaceous plants like the potato and tomato, the stem may unite at any portion where the cut surfaces come in contact. To make a neat and thoroughly satisfactory graft, however, it is of course desirable to select stems of exactly the same size.

The splice graft, elsewhere described, is the best one to use, and if the incisions are made with care, so that the incised surfaces fit accurately together, it is only necessary to tie a piece of cloth about the united stems for a few days until union has taken place. It is not necessary to use grafting wax, if protected from winds and too hot sun. The operation is preferably performed in the greenhouse.

With this method, I grafted the tops of young tomato plants on the main stalks of potato plants, at a time when the stems were about one-quarter of an inch in diameter. The reverse operation, grafting amputated potato tops on tomato roots, was performed at the same time.

Of course the tomato and potato belong to the same genus, and it seemed reasonable to suppose that such grafting might be successful. But, on the other hand, numerous attempts have been made to hybridize the two plants by cross pollenation, and these have always resulted in failure. I have tried it many times, and have never been able to

fertilize one plant with pollen of the other. We know that, as a rule, plants that cannot be cross-pollenized cannot be mutually grafted. The same barriers usually exist in one case as in the other.

The potato and tomato grafts, however, proved very notable exceptions to this rule. In both combinations, the union between the foreign stems took place quickly, and resulted in a stem as strong as the ordinary stem of either plant. Growth continued, and the plants came to maturity at about the expected season.

But the results of the strange alliance were interesting to the last degree.

They must be considered in detail because they have a bearing on one of the most interesting open problems of plant development—the question of sap hybridism.

Potatoes Grown on Tomato Vines

The tomatoes that grew on the root-stalks of the potato developed much as other tomato vines do, although in some cases it seemed that the vines bore closer resemblance to potato vines than is usual. But the fruit that appeared in due season was a tomato differing in no very obvious respect from other tomatoes of the same variety. They, however, were not of as good quality.

Meantime the potato roots, which supplied water and mineral salts to the tomato vine above

A Tropical Solanum

This is a cousin of the tomato and potato, and it came to Mr. Burbank's garden from Brazil; at least its ancestors did. The variety here shown has been greatly improved through selection, and has been made to give up the major part of the annoying spines that its progenitors wore. The plant bears a tomato-like fruit, and Mr. Burbank contemplates attempting to hybridize it with the tomato. The result should have great interest.

them, and which in turn must receive material for the growing of their tubers from that vine, showed quite unmistakably the influence of the foreign system of leaves with which they were associated.

Instead of being smooth and symmetrical like ordinary potatoes the tubers were small and ill-shaped, and some of them had rough and corrugated scale-like surfaces, suggesting the skin of a lizard rather than that of a potato. Moreover, they were bitter in flavor and utterly unlike the ordinary potato in taste. They further showed their departure from the traditions of their kind by manifesting a tendency to sprout even while the tomato top was still growing vigorously.

Perhaps these results, as regards both the relative normality of the tomatoes borne by the grafted vine, and the abnormality of the potatoes grown by the roots, might have been expected. At least they seemed quite explicable.

It will be recalled that the conditions of plant growth were detailed somewhat at length in the first chapter of the present volume, and that it was there pointed out that the plant roots absorb from the soil about them mineral salts in solution that are carried up to the leaves of the plant before they are transformed into organic matter by combination with carbon drawn from the air. It was noted that the organic compounds thus

manufactured in the leaves of the plant must be sent back down the stem of the plant to be deposited, in case of a tuber-forming plant like the potato, in connection with the roots in the ground.

It follows, then, that the tomato plant, even though its source of supply was the root system of a potato, merely gained from these roots part of the raw inorganic materials with which its leaves were to manufacture the special compounds that go to make up a tomato. Inasmuch as the tomato leaves were themselves unmodified, there was no reason why their product, the tomato, should be greatly modified.

In receiving its supply of raw material from a foreign root, the tomato top was in no different condition from the ordinary cions in a fruit orchard, which, as we have seen, are habitually grafted on roots or branches of a foreign species.

But the case of the potato tubers is obviously quite different. Their substance is made up of material that came originally, to be sure, in part from material gathered by potato roots; but this material had traveled up to the leaves of the tomato plant and had there been transformed; so when it returned to be deposited and form tubers it was a tomato compound and not a potato compound.

It was not absolutely different in material from

Potatoes With a Strange History

These are potatoes grown on a vine on whose stalk a tomato top had been engrafted. The tomato leaves were unable, apparently, to supply just the right kind of material in abundance for the making of the best varieties of potatoes; but they made a creditable effort nevertheless. Considering that no tomato vine had ever grown a potato at all before, the result might be said to be notable.

the material of the ordinary potato, because the tomato and potato are cousins.

But the modification had been great enough to transform the tuber, and make it a deformed and perverted thing, more or less comparable, doubtless, to the tubers of some ancestral race from which both the tomato and potato have developed.

The extraordinary thing, perhaps, was that the tomato should have manufactured starch in such quantity as to have supplied material for even these dwarf tubers, inasmuch as the normal tomato plant produces no tubers of its own. But seemingly the buds designed to produce tubers on the potato roots made an incessant appeal that the vine above could not resist, even though it was able to fulfil but imperfectly the specifications for a potato tuber.

Aerial Potatoes

Meantime, what of the potato tops that were grafted on the stem of the tomato? How did these prosper?

Here, it is obvious, were complications of a different order. The tomato vine obviously could bear no tomatoes because it had no tops. Meantime the potato vine was equally handicapped as to the production of subterranean tubers since it had no roots of its own kind.

But the tomato roots of course sent up their

supply of water and salts in solution, and the potato leaves set to work as usual developing material for the manufacture of tubers. When, however, the effort was made to send this material for tuber formation back to the roots, there was an embargo put on such transportation because the tomato roots have no knowledge of the art of tuber making.

In this dilemma the potato crop, under spell of the compelling instinct of tuber formation, made the only compromise possible by growing aerial tubers at the joints where the leaves appear from buds springing from the point of union with the leaves of the stem.

What would ordinarily have been leaf-bearing branches were terminated with small potatoes, which, because of exposure to the sunlight, generally took on a greenish tint, those in full sunlight sometimes being thoroughly green, while those that were shaded by leaves were of a lighter color.

The potato vine growing on a tomato stem and bedecked with aerial potatoes, like some strange form of exotic fruit, was certainly one of the most curious forms of plants ever seen. It is perhaps needless to add that the potato vine produced no fruit that gave any suggestion of the influence of the tomato. The tubers it grew were potatoes and nothing else; their modifications in form and color

Odd Cousins of The Tomato

These curious products are potatoes of a strange tropical variety; representatives, probably, of a type of plant somewhat intermediate between the modern developed varieties of tomato and potato. The attempt to hybridize the potato and the tomato should be carried out persistently, for if hybridization could be effected, the results would be extraordinary; and Mr. Burbank's success in grafting the two plants suggests that the thing is not impossible.

were obviously due to the lack of their natural protective soil covering.

But the fact that the vine, handicapped by lack of roots of its own kind, should have been able to transform leaf buds into tuber-growing aerial rootlets furnishes an interesting lesson in the metamorphosis of parts. How the great poet Goethe, who first expounded the theory of metamorphosis of parts, and clearly recognized the fundamental unity of stem and leaf and flower, would have enjoyed the viewing of a spectacle like that!

Questions of Sap Hybridism

And for the modern plant developer, the strange compound vines have no less interest, for they suggest a number of questions that are much easier to ask than to answer.

How, for example, was the leaf system of the potato that grew the aerial tubers to know that tubers were not being formed about its roots in the ordinary way? It did know this, obviously, else it would not have adopted the unprecedented expedient of growing tubers in the air.

It is easy to speculate, and to suggest, for example, that the potato plant producing an excess of sugar and starch in the usual way, must find some place to deposit it, and that as no demand came from the roots, the only available buds were made to do vicarious service. But the explanation

obviously lacks a good deal of complete satisfactoriness. For the moment, we perhaps must be content to recognize in this another illustration of the fact of communication between the different parts of a plant, and of the harmony of purpose through which the plant as a whole is made to respond to the conditions of the environment in the way that best meets its needs.

But we are forced to recognize, through such an illustration, a greater capacity for adaptation, seemingly almost of a reasoned character, than we are commonly wont to ascribe to the plant.

The case of the tomato plant growing on the potato roots, which so perverted the character of the tubers that it supplied, has practical interest for the plant breeder, and in particular for the orchardist, because it demonstrates the effect of a cion on the stalk on which it is grafted. Of course the ordinary fruit tree does not develop a system of tubers, and so it does not call for such a supply of starch, for example, as that which the tomato vine was induced to produce for the tomato roots. But the root system of any tree requires nourishment if it is to develop, and this nourishment, as we have seen, must be supplied by the leaves of the tree above it, even though the roots themselves first collect part of the materials.

It follows that the root system of any tree, while

it is absolutely essential to the leaf system above it, is also very largely dependent on that system.

In other words, there is the closest reciprocal relation between root system and leaf system.

This relationship, which many orchardists overlook, I have long recognized and have repeatedly referred to. But the case of the tomato on the potato root emphasizes the lesson in such terms that no one can ignore it. With this illustration before us, we can scarcely doubt that the root system of any stock on which a foreign top is grafted (as is the custom in most orchards) is modified in some measure by the cions it bears. The foreign leaves cannot supply precisely the same quality of nourishment to the root that leaves of its own kind would have supplied.

In the main, no doubt, the protoplasm of the root assimilates the nourishment that comes to it, and makes it over into its own kind of protoplasm. But we know that the flesh of animals varies in quality with the food given the animal, and we cannot well doubt that the protoplasm of the root of a plant must similarly be modified by the character of its food.

And this line of thought suggests the further possibility that when more cions than one are grafted on the same branch or on the same trunk, there must be a certain intermingling of the sap

Some Selected Tomatoes

These tomatoes show the results of selection, without hybridization. There is a good deal of variation among the fruit from the same tomato vine, and still more on neighboring vines; and it is not at all difficult to develop characteristic types by selective breeding.

from the different leaf systems in the course of the journey to the roots of the tree; and that it might very conceivably happen that a sufficient blending would take place so that the modified sap might find its way to the fruit buds of a given cion, and effect the character of the fruit in a way not altogether unlike the effect of hybridizing.

This would account for the case narrated at length in an earlier chapter, in which a cion of the purple-leaved plum grafted on the stem of a green-leaved Kelsey plum tree, appeared to influence the fruit of a neighboring stem so that the seedlings that grew from that fruit bore purple leaves.

As before stated, such a striking instance of evident "sap hybridism" is exceedingly rare; but can we be sure that influences of a less tangible character are not constantly exerted by engrafted limbs?

May it not be possible, even, that the influence of cions from many sources on one another, when they are placed together in large numbers on a single tree, as in the case of my colonies of plums and cherries and apples, may be very notable indeed, even though of such character as not to be demonstrable? Is it not at least possible that the improved quality of the new and splendid varieties that appear on the various cions of these multiple

trees, is in some minor part to be ascribed to the mutual influence of cions of many different strains of past generations, one on another?

If this thought be permitted, we must recognize in such fruit colonies as those in question an influence exercised by the community for the benefit of the individual that is comparable to the intangible influences through which a community of human beings affects the moral character of its individual citizens.

All this carries us somewhat afield from the case of our grafted tomato-potatoes, but only to the extent of a natural application of principles clearly suggested by the phenomena exhibited by these extraordinary plants.

A Glance Ahead

Let us repeat that the grafting of these two plants is not a difficult procedure.

It is well worth the effort of any amateur to repeat these experiments (so far as I know, this has not been done until recently, and its significance has never been fully appreciated), and to observe for himself the curious phenomena that will result.

Possibly the results of my own early experiments might not be exactly duplicated. But there is little doubt that interesting and encouraging developments would result.

Pink Chives and Other Foods for Flavor

Some Successful Work With The Onion Family

THAT there is such a thing as being too popular, many plants have learned to their sorrow. For popularity, with the plant, implies a kind of attractiveness that results in the plant being eaten by some herbivorous animal. The animals can secure food in no other way, so they are not to be blamed for their marauding. But in the meantime the appeasing of their appetites spells destruction for the succulent herbs.

The only resource of the plants is either to develop extraordinary capacity to thrive under adversity, as the familiar lawn grasses do; or to develop weapons of defense.

These defensive measures may take the form of a tough and indigestible fiber as in the case of woody shrubs; the studding of the plant surface with spines as with the blackberry; the production

of a crop of stinging hairs as with the nettle; or the secretion of oils or other chemicals that have offensive odors, or bitter, acrid, or peppery taste.

In the present chapter we are concerned with a conglomerate group of plants that have resorted to the last-named expedient in the attempt to protect themselves against the unwelcome attentions of herbivorous beasts. The onion and its allies, the mints, mustard, peppers, and the others of this company, are for the most part lowly herbs or succulent bushes that have qualities of flesh that make them attractive. In self-defense they have developed added qualities, chiefly through the manufacture of essential oils, of odors or flavors that are the opposite of appealing.

But as in a good many other instances, these plants by their very zeal to some extent defeat their own purposes. The unique quality of the flavors they develop, even though at first repellent to the palate, serve as a stimulus to the receptive mind of man, and urge him to develop a taste for the very things which at first seemed repellent.

So it has happened that plants that seem by the very nature of their product to be denied presence on the table have come to be regarded everywhere as admirable accessories to the dietary, supplying flavors that pique the appetite and facilitate digestion. These stimulators of jaded

Chilean Garlic On the Stalk

This is the improved garlic shown in the preceding picture. It will be seen to have grown to seemingly ungarlic-like proportions under stimulus of changed climate and skillful tutelage. The garlic experiments are still under way at Santa Rosa.

appetites are perhaps of somewhat doubtful benefit, if we are to accept the findings of the physiologist, but they have a recognized place in the modern kitchen, and various and sundry of them are among the most important of garden vegetables.

At the head of the list, doubtless, if we consider universality of vogue, are the members of the onion family, including onions proper of many varieties, and such allied species as the garlic, the leek, and the chive.

Work With The Chive

I have worked a good deal with most of these, but have found perhaps greatest interest in developing the one of them that is least generally known —the chive. The particular work of recent years with this plant has had to do with a variety which bore a flower that was originally dull crimson in color, and which, notwithstanding its disagreeable odor, appeared to combine the qualities of a border plant with those of a food plant.

I secured seed of this variety of chive in Europe and raised seedlings for five years, carefully selecting in each generation the ones that most appealed. There was a considerable tendency to vary within rather narrow limits, some plants being deeper in color than others, but the divergence was not at first very marked.

In the third year, however, there suddenly

appeared a mutant having a blossom of bright red color instead of the usual rather dull crimson.

As the chive can be multiplied indefinitely by division, this single plant might have become the progenitor of a race of red flowering chives. But I wished to see what the hereditary tendency would be, and so raised about ten thousand seedlings from the red flowering stock. Nearly all of these seedlings reverted to a pink color. There had been a faint tinge of rosy pink in the original flower, obscured by the crimson, but the new seedlings bore blossoms of a pleasing pink color, and constitute a new and highly attractive variety.

While thus developing a pleasing flower and thereby adding to the attractiveness of the chive as a border plant, I paid attention also to the bulb and stalk of the plant itself as well as to the flavor.

In the course of five or six generations I developed the bulb so that the average size is about twenty times that of the bulbs of the stock with which we began.

Thus the new race of chives not only supplies a pink flower which has a very handsome effect when massed in contrast with the characterless flowers of its ancestor, but it is also relatively gigantic in bulb as compared with them. Thus its value as an ornamental plant and its utility as

An Improved Garlic

This is a garlic from Chile that has been undergoing education in Mr. Burbank's experiment gardens for a number of years. At the right is seen a head of the original form, as imported from South America; at the left its developed and greatly enlarged and improved descendant. It is obvious that the climate of the northern hemisphere—at all events the climate of California—agrees with this particular garlic.

a food plant were enhanced simultaneously, and somewhat in the same proportion.

These results have been attained by selective breeding, without hybridizing, in the course of a comparatively small number of generations.

Development has progressed along yet another line. The one chief objectionable feature of plants of this tribe, as every one knows, is their odor. But it is well-known also that different members of the onion tribe differ greatly in this regard. In recent years the Italian and Bermuda onions, which are very mild and relatively odorless, have been introduced, and the possibility of removing from the members of the tribe their objectionable odor has come to be more generally recognized. It appears that the Italian varieties have been rendered odorless by selection from ordinary onions. Some of the improved Italian varieties are so mild in taste that they can be eaten like an apple.

In experimenting with the chive I have naturally not overlooked this quality, and some of these improved varieties show a marked advance upon its ancestors in regard to odoriferousness as in regard to size and quality of bulb and beauty of flower.

Improving Other Onions

My work with the other members of the family

has been fairly extensive, inasmuch as I have experimented first and last with about fifty species of wild and cultivated *Alliums* (that being the technical name of the genus) from Europe, Asia, and America, and with various forms from Chile and from China.

The onion is a very interesting plant with which to work, from the fact that it shows a good measure of responsiveness. The wild onions are exceedingly variable and the cultivated species no less so. Indeed, this might be taken almost for granted considering the long period during which the onion has been under cultivation and the large number of varieties that are in existence.

In addition to the ordinary species with its well-known qualities, there are numerous handsome-flowering varieties of onion. And in the Sierras there is also a variety growing along the mountain streams which has a delicious, sweet flavor much superior to the cultivated onion. I have cultivated also an onion from China which is peculiarly sweet flavored.

Some of the Chilean and Canadian leeks that I have had under cultivation differ widely in form from their Northern relatives. Some of the Chilean wild garlics have been classified as leeks by the botanists and gardeners in this vicinity; whereas the same observers classify certain of the true

Burbank Onions Grown for Seed

Mr. Burbank has worked extensively with the onion, as with numerous other members of the tribe of alliums. Here we see a field of perfected Burbank onions that have been allowed to go to seed. The excellent character of the bulbs may be inferred from the size and vigorous development of the tops.

leeks as garlics; which suggests the divergence of form of these South American species.

I am now cultivating a wild garlic from the mountains of Chile which is a wholly distinct species from the common cultivated garlic, having much larger bulbs and a taller stalk similar to that of the leek.

I have in contemplation the hybridizing of this Chilean garlic plant with the familiar form of cultivated garlic. My attempts to cross the species with the onions have not met with success, although I still think it possible that this cross may be effected.

My large collection of flowering *Alliums* from California and other countries has of course been made with the expectation of hybridizing these plants among themselves or with commoner varieties of the onion. There are interesting possibilities of development all along the line.

There is a Spanish onion named the Prize-Taker because of the extraordinary size of the bulb, which sometimes attains a weight of five or six pounds. That new developments, perhaps of unexpected character, will result when the varied races from Europe, Asia, China, and Chile are blended with American stock, is quite to be expected.

The onion is not very easy to hybridize because

of its small flowers. But it is only necessary to use reasonable care to effect hybridization, and the results are likely to repay the effort.

Indeed, whether by hybridizing or by mere selection, the onion is susceptible of great improvement along almost any line one may choose. The odor, for example, may very readily be intensified or decreased, and the size and flavor modified. On the whole I regard this as one of the most interesting vegetables with which to work. But there are many other plants prized for their flavor that also merit attention.

The Parsley Family

Prominent among these are the members of the parsley family.

The common parsley and its close relative the caraway vary a good deal in flavor in individual plants grown from the same lot of seed. Only persons with a developed or specialized sense of taste are likely to notice this, however.

To the person who tastes them carefully, it will be obvious that some specimens are much sweeter and better flavored than others.

But as the general public is not very discriminating, it is perhaps doubtful whether it would be profitable to develop these into fixed varieties. The market for these plants is of course restricted at best.

A South American Allium

Here is a plant with a nightcap; or, if you prefer, a dunce-cap. The protective covering of the flower-bud has burst open, but has not been discarded; hence the curious effect. This is not, as might be supposed, a mere accidental individual peculiarity, but is characteristic of the species. It might be difficult to guess, however, what protective function the nightcap subserves.

A more tangible property, and one that is likely to appeal to the user of the plant, is the shape and quality of the leaves. I have worked on the curled parsley to some extent and have found that by careful selection it can be improved greatly in a few years. The different tendencies of the leaves can be fixed quite readily in three or four generations.

At one time I also developed a golden-leaved parsley, something like the golden-leaved celery. This was a plant of great promise and I expected to introduce it. But greatly to my regret, it was destroyed by millipeds just before it was ready to produce seed.

I have never seen another specimen, but of course similar mutants might appear at any time, for what has happened once to a plant may happen again.

Another genus of the parsley family, *Ligusticum* of the botanist and commonly known as lovage, is cultivated to some extent in our gardens for its aromatic seeds. There is a California species (*L. Canadense*) that grows along the ground, and seeds quite commonly in Northern California. The root is gathered and used by the Chinese.

I have worked with this and with several allied species very extensively for a number of years.

There are several native species or varieties of this family that are hard to differentiate, especially as they vary widely in different localities. All have seeds or roots with a characteristic pungent odor, but the quality of the odor varies throughout the widest range, from the most fragrant and attractive to the most disagreeable.

Undoubtedly some of these wild species offer opportunities for development through cultivation and selective breeding. My own work in this regard has scarcely passed the experimental stage, however, even though it has involved a large number of species and varieties. There is opportunity for interesting and valuable work in the development of the possibilities of these bearers of flavors that appeal to the palate.

Mints and Their Allies

I think I have grown all the mints and pot herbs that have been under cultivation, and have found them without exception variable in quality when grown from the seed.

Indeed, to the persons who taste them with care, it will appear that variation is the universal rule. Each individual plant when grown from seed has a slight difference in fragrance, and in the amount of essential oil that it contains; this oil being, of course, the source of the fragrance. It is not difficult by selection alone to obtain varie-

A Burbank Allium

This is another of the company of alliums with which Mr. Burbank has experimented extensively. The relationship with the onion is shown in the form of leaf and, particularly, in the flower head. Some of Mr. Burbank's alliums have really handsome flowers; and an ornamental onion is certainly an interesting anomaly.

ties that are of exceptionally fine fragrance and that produce a relatively large percentage of the essential oil for which the plants are usually grown.

When a new variety has been obtained, it is not necessary to fix it so that it will breed exactly true from the seed; for the most of these plants can be increased by division.

The mints hybridize naturally where various species grow in the same vicinity, as we have pointed out in another connection.

In this way natural hybrids are sometimes produced that are so vigorous as to replace the original parent plants in the state of nature, driving them out of existence on their own ground. Among hybrid mints, whether natural or produced by hand pollenation, there will be seedlings that grow with exceptional rapidity, and that present peculiar shapes and much variation as to roughness and smoothness of leaves and form of the spikes and blossoms. In my work with all these plants, I found that quality was the one thing lacking. In any lot of seedlings grown from the pot-herbs or plants some individuals have odors that are positively disgusting, and those of some add nothing to the value of the plants, but detract when mixed with the better ones.

All this is quite what might be expected when

we reflect that the mints are a rather numerous family—that fact by itself proving their tendency to variation.

Among the mints that I have worked on recently are species from South America that resemble the peppermint yet are in some respects distinct. An unnamed species with a tendency to cling to the ground more closely than other mints and growing so rapidly as soon to cover a large surface gives considerable promise.

A species said to be hardy, sent by my collector from the mountains of Southern Chile, has somewhat the fragrance of the native peppermint. The *yerba buena* (*Micromeria douglassi*) is a common little trailing plant in the red wood forests, sometimes growing also among shrubs and along the edge of fields. It has sweet-scented, round leaves, and small, pale, insignificant, purplish flowers.

This plant is fairly constant in any given locality, but specimens from different regions vary a good deal, some being rather packed growers while others run out to great lengths, with long, runner-like branches. A species of this plant of exactly the same flavor, but growing as a shrub, with brilliant fuchsia-like flowers, has been sent me from the high mountains of Chile. These evidently sprang from one original ancestor, but in our California varieties it is an insignificant trail-

Pink and Yellow Chives

The pink chive is one of Mr. Burbank's most interesting productions among the tribe of alliums. It is an ornamental border plant, with altogether attractive flowers, yet it retains the characteristic succulence for which the chive is prized. The pink chive was developed purely through selection, without hybridizing.

ing plant, and its relative of the Southern hemisphere is a tall shrubby plant with brilliantly colored flowers. The Chilean plant is also called yerba buena.

I have attempted to cross this plant with the species from Chile, hoping thus to stimulate variation and perhaps to produce a plant of larger size, and through selection a variety of permanent value. But the flowers of the plant are quite small, making the process of cross-pollenization a rather delicate one, and my experiment has hitherto not proved successful. This, however, is doubtless due to operating on too small a scale. I have no doubt that more persistent efforts will result in hybridizing these species, notwithstanding they came from different hemispheres.

Other mints with which I work are the melissa or balm, and the common garden thyme.

Of the former I have raised many thousands of plants from seed, and have secured among these half a dozen in which the flavor and aroma are exceptionally pure and strong. In one of these individuals the flavor is so much more spicy than is usual that it may be said to constitute almost a new type of flavor. The experiments in improving the plant are still under way and the response made by the plant itself is prompt, giving assurance of the production of improved varieties. And

scores of other plants of similar nature have given like results, but need not be specifically mentioned here.

The thyme also I have grown from the seed, and have noted with this as with other members of the family a very marked tendency to variation. The most interesting variety that I have developed has been produced by selection from a seedling the leaves of which showed a beautiful white center with very uniform edges of a dark green, instead of the usual yellow and green markings.

This plant, in addition to its beautiful leaf, was a more compact grower than the old variegated thyme. By selecting through successive generations I accentuated and fixed the novel leaf until it would come almost uniformly true from the seed. I offered this new ornamental variety to a dealer, but he responded that the demand for thyme was so small as not to justify its purchase. So the new plant was allowed to drop out of cultivation.

The Mustard Family

The members of this family, quite unrelated botanically to the ones we have considered, illustrate the tendencies of different races of plants to adopt similar expedients in furthering their ends.

Being succulent herbs, like the parsleys and mints, the mustards have devised a similar pro-

Horse Radish Plants

The horse radish belongs to the small company of plants that have given up the habit of producing seed. It is propagated solely by division, and therefore is not subject to improvement by selective breeding. Mr. Burbank once facetiously offered to give a thousand dollars an ounce for horseradish seed. He received many packages of seeds in response to this offer; but none of them produced horseradish plants. Mr. Burbank says the offer is still open, but there is small probability that any one will win the prize, for the horseradish seems to have permanently abandoned the habit of seed production.

tective measure, namely the development of essential oils that have a pungent and biting taste. But here as with the others man has cultivated a taste for what seemed a prohibitive quality, and the mustards, including not only the plants that give their name to the family, but such allies as the peppergrass, the cresses, and the horseradish, have long held a secure place in the culinary department of every household.

My most extensive experiments in the cultivation of the mustard were carried out some thirty-five years ago. I worked quite largely with the Japanese and Chinese mustards, in combination with the common European mustard.

These Japanese and Chinese mustards are quite distinct from our species. One kind very extensively used in China, and introduced by the Chinese in California, has the appearance of a large compact bunch of celery. The leaves are perhaps two inches in width or even more, growing so compactly that the plant is even more solid than an ordinary cabbage head, each plant weighing from two to five pounds. The leaves are blanched like celery. They have a spicy taste suggestive of mustard that is very palatable and refreshing. The plants are cooked like other garden vegetables.

Another Chinese variety has greener leaves and

a looser habit of growth, the plant being also considerably larger. This also is a pleasant, spicy vegetable when cooked.

All the Chinese mustards run to seed quickly at the approach of warm weather, so the seed is usually sown quite early in the winter. The young plants are stimulated to rapid growth by good cultivation and fertilization, and fine large plants are ready for the market in the early spring. The plants are usually grown on raised beds and are planted about a foot apart each way. These are really remarkable vegetables that should be much more generally cultivated in the United States.

In the Northern States, unless planted very early in cold frames, they run to seed without forming the large, succulent head that gives them value.

Both the black and white mustard are common plants in California, the black mustard in particular being prized for culinary purposes when young and tender early in the spring and winter. The white mustard grows in enormous quantities in the fields, especially in the region about Monterey Bay, where the seed is collected by the ton, to be ground into commercial mustard. The white mustard in particular may become a pest, as it is exceedingly difficult to eradicate it, the seeds

Improved Mustard

The mustard is a plant to which the ordinary amateur gardener pays very little attention. "Mustard is mustard," would probably be his comment, and it would not occur to him that the plant is one having any particular interest from the standpoint of the would-be plant developer. In point of fact, however, there is a good range of variation between different mustards, and Mr. Burbank has seized on these variations for material to work conspicuous improvements, notably as regards the amount and quality of the pungent principle for which the mustard seed is prized.

sometimes remaining in the ground several years, part of them germinating each season.

About the only way to eradicate it completely from the grain and other crops, is to pull it just as it comes into bloom in successive seasons.

My systematic work of selective breeding of the mustards was carried out while making similar experiments with other members of the family, including the turnips, cabbages, and radishes. I developed some superior varieties by selection, and sent the seed east to various parts of the world. But the demand was small and I presently discontinued work with these plants, although several of these and similar varieties developed are still catalogued by some American and European seedsmen.

Other Crucifers that the gardener thinks of collectively, though they represent various genera, are the peppergrass and the various cresses, including the nasturtium.

The common peppergrass is as variable as the lettuce. There are large numbers of plants horticulturally called cresses, with a considerable range of variation.

One of the most interesting forms with which I have worked is a Chilean cress (*Nasturtium Chilensi*), which is as tender as the common water cress during the rainy season, and which has an

astonishing ability to resist drought. This Chilean variety will withstand our summer, even if exposed to the blazing sun, and after a period of dormancy will revive and grow freely as soon as the fall and winter rains come.

My experiments with it have been confined to selection for the development of varieties showing the best qualities of the plant.

With the peppergrass I have worked somewhat more extensively. Some specimens of this plant have very finely dissected leaves. I have worked to develop this variety, producing leaves very similar to those of the improved varieties of parsley.

The plant is rather obstinate, but I have nevertheless been successful in developing and fixing varieties having many of the desired characteristics.

As the peppergrass is an annual it is of course necessary to fix the new qualities so that they will be reproduced in the seedlings. It is this rather than the mere production of the variety that offers difficulties.

The familiar horseradish offers a notable contrast to the peppergrass and to most other members of the family in the matter of seed. For whereas the mustard, radish, turnip, cresses, and the rest produce seed in the greatest possible

A Basket of Peppers

Like most other products of the garden, the pepper has come under Mr. Burbank's careful scrutiny, and has felt the benefit of his guiding hand. The large and handsome specimens here shown have been developed in the course of a few generations of selective breeding, without hybridization. Similar results will attend the efforts of any one who will go about the work of improving the pepper with enthusiasm and zeal, using the ordinary garden variety. The plant deserves to be cultivated much more generally than it is.

abundance, the horseradish produces no seeds at all.

The horseradish does, indeed, bloom with the greatest profusion. But the blossoms prove sterile. The plant has entirely and probably forever lost the power of producing seed.

I have elsewhere referred to the fact of my having created a small commotion among amateur gardeners by the joking offer of one thousand dollars an ounce for horseradish seed. Of course I knew that no horseradish seeds were to be had, yet I would gladly have given then, and I would gladly now pay, at the rate of $1,000 an ounce for horseradish seed. But there is not the remotest probability that any one will ever legitimately claim the prize. If the seed should ever be found, it will probably be dark colored, about the size of a common black mustard seed.

I have received nearly or quite a thousand letters informing me that the parties writing could supply me with all the horseradish seed I could wish, inasmuch as their plants were blooming abundantly.

I may add that I subsequently received large quantities of dried horseradish buds, as well as great quantities of the seeds of weeds of various sorts. I have even received what were alleged to be horseradish seeds from market gardeners. But

the plants that grew from these seeds bore no resemblance to the horseradish.

The interesting features of this loss of the power of seed production by plants that have for long periods been propagated by the root or from cuttings or tubers—including plants of such diverse races as the banana, the pineapple, the sugar-cane, and the potato, and nearly all plants generally cultivated in greenhouses, along with the horseradish—have elsewhere been referred to. I may add that the loss of power to produce seeds in the case of the potato is not of necessity complementary to the capacity to produce tubers. For at least once in my experience a potato plant that by rare exception produced seed developed at the same time some of the largest tubers that I have ever seen.

Nevertheless there is an association between seed production and development of the root system, as we have seen illustrated. And it is not unlikely that development of the root of the horseradish may have had an influence on its seed-bearing capacity. It may be recalled that the carrot and parsnip which produce roots somewhat suggestive of that of the horseradish in shape and relative size, are biennials, and do not take on the functions of root and of seed-development in the same season.

The roots are formed in the first year partly at least to supply nourishment for the development of the stem and flowers and seeds in the ensuing season.

Whatever the relation between the root of the horseradish and its lack of fertility, the fact remains that the plant is propagated solely by division, and that hence there is very little opportunity for the development of new varieties or the improvement of old ones. Each horseradish root is in effect a part of an original plant now endlessly divided, and the variation in different roots depends upon conditions of cultivation or nourishment, not upon inherent differences between the different plants.

It may chance some day that an exceptional horseradish plant will produce seed, just as an exceptional potato plant does from time to time.

In that case there will doubtless be opportunity to improve the horseradish somewhat as I was able to improve the potato by growing plants from the seed.

But until such an exceptional seed-bearer is found, we must accept the horseradish as it is, and admit our powerlessness to change it markedly.

The Peppers

The versatile family of Solanums, several members of which have already claimed our

Giant Mexican Peppers

There is good opportunity for the development of new varieties of peppers through the blending of strains of various races, as several are available. Peppers grow far to the North, but they were originally of semi-tropical habitat. This handsome specimen from Mexico is being utilized by Mr. Burbank in some crossbreeding experiments.

attention, supplies an important group of plants that are prominent among the producers of pungent and aromatic flavors.

These relatives of the sunberry, tomato, potato, and eggplant, are the peppers, of which there are large numbers of cultivated varieties in different countries.

The different peppers vary from the size of a barleycorn to that of a very large apple, and in color from black through scarlet, crimson, orange, and yellow to pure white. In form, some are nearly flat, others oval, yet others round or heart-shaped, or like drawn-out cylinders. Some are annuals and others perennials. As to flavor, some are sweet and palatable, while others are among the most pungent and fiery of substances that are ever purposely put into the mouth.

I have worked quite extensively with the peppers, hybridizing them in various ways, and raising large numbers of the seedlings.

In crossing the very small varieties with the very large ones, and the very light-colored with the very dark-colored, one produces the most unusual combinations. Even in the first generation some bushes appear having diminutive fruits and others having unusually large ones; and there is a display of different colors, including stripes, that is quite beyond prediction.

Occasionally, though not often, fruit of different colors will appear on the same plant.

Some hundreds of varieties of pepper have been described, but only perhaps less than a dozen are cultivated ordinarily in the gardens of temperate climates.

The large sweet peppers are becoming popular. In some varieties, they are almost mild enough in quality to take the place of their relative the tomato.

My own work has included the cultivation and crossing of a large number of species and varieties of pepper. At least one of these will stand a very low temperature, the plants showing no trace of injury when left where ice forms a quarter of an inch in thickness.

As most of the peppers are exceedingly sensitive to frost, this hardy Chilean variety seems to offer opportunities for hybridizing experiments through which other varieties of the plant which at present are of restricted habitat may be made suitable for growth in cold climates.

I have just referred to the great diversity of forms shown by such hybrids.

There can be no question that selection among these and breeding through successive generations would produce almost any desired combination of qualities.

Artichokes in Mr. Burbank's Back Yard

Mr. Burbank feels that the artichoke has been more neglected than almost any other plant that invites the gardener, particularly in this country. It is highly appreciated in southern Europe, but until somewhat recently has been comparatively little cultivated in America. It will be seen from this picture that Mr. Burbank himself is giving the artichokes full recognition. This handsome growth was to be seen last summer in his back yard.

Artichokes and Some Garden Specialties

Finding New Food Plants Wild in the Woods

DOUBTLESS the greatest labor-saving scheme ever devised by any flower to meet its essential needs is that adopted by the Sunflower family—the tribe popularly represented by the sunflowers, asters, thistles, and daisies.

The botanist classifies the members of this tribe as *Compositae* or Compound Flowers. The name might be misleading if taken to imply that the flowers of this family differ essentially from other flowers. In point of fact, the individual flowers of this tribe are in all essentials of pistil and stamen like other flowers. So the modern botanist objects to the name "Compound" as applied to them, although he retains the Latin title that they have borne for some centuries.

But if we properly interpret the term, the name "compound flower" seems appropriate enough,

inasmuch as what would commonly be called a single blossom—say a single daisy, or aster, or dandelion, or thistle—is in reality made up of a very large number of individual flowers grouped together into a floral community, which advertises its location to the insects by arranging a single circle of petaloid colored emblems that do service for the entire community.

A Measure of Economy

The economy of this arrangement, in the matter of saving of plant energy, is obvious.

Flowers that have not adopted this system are obliged to supply a colored advertising emblem for each individual set of stamens and pistils. These composite flowers make one such floral emblem serve the purpose of scores or even hundreds of flowers.

Of course the floral community, even though the individual flowers are very small, occupies considerable room. It is necessary, therefore, to provide a largish receptacle to hold the flowers, and in particular to hold their seeds when developed. The outside of this receptacle is usually covered, for protection, by overlapping series of scaly bracts or little leaves that form a sort of armor.

A glance at a sunflower will illustrate the plan that has been pretty generally adopted in the

Another Burbank Dooryard View

So strong has been the appeal of the artichokes to Mr. Burbank, that they have been permitted to invade his front dooryard as well. Here is a wonderful group of them, photographed just at blossoming time. As the fence in the foreground is of ordinary height, an idea may be gained of the enormous size of the artichokes which tower above it.

provision of a covering to shield the flower-village, particularly during its early development.

Edible Flower-Heads

In at least one case, a plant of the tribe has been induced to develop this receptacle until the leaves of its scale-like covering have been enlarged and thickened and made succulent at their base, so that they are edible; the receptacle on which the flowerets grow being correspondingly developed.

The flower that has thus been induced to put itself at the service of man and add to the delicacies of his dietary is known as the artichoke.

This plant is widely cultivated in Southern Europe and is exceedingly popular there. In Italy, indeed, it occupies in some regions about the position in the dietary of the masses that the potato does in Northern Europe and America. In this country, however, the artichoke has only somewhat recently begun to gain popularity. As the manner of its cultivation is better understood, it will doubtless gain wider vogue, for its leaf scales and pulpy receptacle are regarded as delicacies by epicures everywhere.

I have worked somewhat extensively with the artichoke in very recent years, beginning with the French Globe artichoke and the Oval Brittany artichoke in 1908; subsequently using also the Paris

More Artichokes

This picture shows some heads of Mr. Burbank's improved artichokes, taken just before the buds were ready to burst. For table use the flowers are never allowed to open, as the bracts would then be practically inedible. But these artichokes in Mr. Burbank's garden are intended for breeding purposes, and they will be allowed to come to maturity, and the best of them used for cross-fertilizing experiments.

artichoke, a large green variety, and of the so-called Perpetual artichoke.

The plants when grown from seed vary markedly in size and shape of the leaf as well as in size of the blossom buds. Some of the plants are thorny. The flowers, if allowed to come to maturity, differ little in color, though greatly in size. Some of the flower receptacles when fully matured open out to a breadth of about twelve inches.

But the flower bud is not permitted to mature to the point of opening when the artichoke is to be used as food. If it reaches the stage when the blue flowerets begin to be visible, the head is altogether too old for eating. The object of cultivating new varieties is not necessarily to increase the number of the flowers themselves, but the flower bud, increasing the size and the quality of the scale-like bud-leaves and the receptacle.

My work has been carried out along the usual lines of selection, and the results have been very satisfactory. Selection has also taken into consideration, as a matter of course, the succulence and especially the flavor of the edible portion.

The improved varieties have flower buds as large as a good sized fist, and are of excellent quality. When in full bloom they are sometimes a foot or more in diameter. They are reproduced

Artichoke Hybrids

This is an individual blossom of one of Mr. Burbank's best hybrid varieties of artichoke. The flowerhead has just passed the period when it would have been in ideal condition for eating, but has not yet fully presented its stamens and pistils. The improvement shown in some of these crossbred artichokes in Mr. Burbank's garden is remarkable; and they are still undergoing development.

with reasonable certainty from seeds, but the method of propagation generally preferred is by the use of suckers which the plant puts out freely. Of course these suckers reproduce the qualities of the individual plant from which they are taken, as roots or grafting cions do in the case of other plants.

When it is understood by gardeners in general that the artichoke can be grown with comparative ease, and that it produces an abundant and never-failing crop of healthful, palatable, and nutritious food, this vegetable is sure to attain far greater popularity.

The Cardoon

The young stems and leaves of the artichoke plant itself are sometimes eaten in Europe. It is necessary to blanch them by covering, somewhat after the manner of celery. There is a modified form of the artichoke, known as the Cardoon, which is cultivated for the stems and leaves instead of for the flower buds. These are blanched by tying the tops of the leaves together and covering the entire plant with straw, banked with earth.

I have grown the cardoon, but have not experimented with it in the attempt to produce variation, as the European cultivators have developed it to a very satisfactory stage.

The plant is very little known in America, but

is likely to be more extensively propagated when its merits are understood.

The Wild Artichoke

Another member of the sunflower family is popularly known as the Jerusalem artichoke, the name having originated, it is said, in a Spanish nickname, amplified to suggest the relationship of the plant to the artichoke just described, which is sometimes spoken of as the Globe artichoke.

The Jerusalem artichoke belongs to the genus *Helianthus,* of which there are numerous species, some of them growing wild in California. It is entirely distinct from the true artichoke, both in growth, appearance, and the purposes for which it is used.

The part of this plant that is sometimes used as food is not the flower bud but a tuber not very remotely suggestive of a potato.

The plants of this tribe are variable, as is usual with plants represented by many species. Some of them bloom abundantly when only six to twelve inches in height, while others grow to a height of ten to fifteen feet. They have very large, broad, heavy leaves, and some of them produce sunflower-like blossoms of enormous size.

Others have small, delicate, slender foliage, and produce small flowers.

The flowers are yellow, the tubers are usually

Round as a Ball

This hybrid Burbank artichoke may be considered almost ideal in form, being practically spherical, and as compact and solid as could be desired. To casual inspection, it scarcely suggests a flower; but to the epicure it suggest what it really is, a most palatable delicacy for the table.

pink, but white varieties have been produced in the past decade.

Some members of the *Helianthus* tribe are perennials, but for the most part they are annuals. They are all easily grown on almost any soil, requiring little or no attention. The member of the tribe known as the Jerusalem artichoke is a somewhat variable plant the tubers of which are chiefly used as food for stock, although sometimes used as a salad.

My own work with the tribe has had to do with the development of the flowers rather than with the tubers. There is one of the annual sunflowers that has a flower quite often sixteen to twenty-four inches in circumference that, if well selected, comes perfectly double, as double as the finest dahlia, producing a most brilliant yellow bloom abundantly. This I have worked on several years to make its flower uniformly double. I have worked with a large number of species of the tribe and have cultivated many field varieties collected in Mexico, California, the Mississippi Valley, and nearly as far north as Hudson Bay.

I have done a good deal of crossing among the seedlings to increase the grace of the plants and delicacy of bloom, and to make the silvery, graceful leaves of one species replace the rough, coarse leaves of another.

There is no great difficulty in hybridizing the various species, especially if care is taken to wash away the pollen by the method described in the chapter on artificial pollenation. But there is great difficulty in fixing a variety after it is formed. The hybrids tend to take on many forms, their variability in the second generation suggesting that of the gourd family.

Of course, this difficulty does not apply in the case of the artichoke, as this may be propagated from tubers, just as the potato is propagated. So any improved variety developed is fixed from the outset. There has not hitherto been enough demand for the plant in this country to stimulate the plant developer to work with it. But it is probable in the near future there will be renewed interest in certain less common garden vegetables, comparable to that shown in recent years in the development of the orchard fruits, and in that case the Jerusalem artichoke is almost certain to receive recognition as a neglected vegetable that is worthy of being generally cultivated.

The Lettuce Tribe

Doubtless the best known member of the composite family under cultivation is the familiar lettuce.

This plant has been so long under cultivation that it is impossible to trace it back to the original

Much Modified in Form

This hybrid artichoke is very different in form from the one last shown. It is much less compact, and makes a somewhat less presentable appearance on the table. Nevertheless it is not without value. as its bracts contain a goodly quality of well-flavored pulp.

wild species. In token of its long cultivation, it is one of the most variable of plants. There are hundreds of varieties of lettuce described in the catalogs but those all quite naturally fall under two distinct groups—the cabbage or head lettuce and the cos or upright growing lettuce, the latter of which is mostly grown in cool, moist climates.

The cos lettuce requires too much care in blanching, and in our dry American climate runs up too quickly to seed in warm weather.

My work with the lettuce was done about ten or twelve years ago, when I experimented in the endeavor to produce different forms, and attained a measure of success. In working with the cos lettuce I endeavored to get a more solid head which would be a very tender compact grower, and would not so quickly run to seed. The part of the lettuce that is eaten is, of course, the leaf, and the plant that runs to seed quickly develops a toughness of leaf fiber that impairs its value.

In hybridizing the lettuce, my usual plan was to get two varieties to bloom as nearly as possible at the same time, and to pollenize by bringing the head of one and rubbing it against the flowerets of the other. The pollen may be removed with a dash of water, as already described, but there is always a measure of uncertainty in cross-pollenizing composite flowers of such small size as those

An Ideal Hybrid

This hybrid artichoke possesses the fourfold advantage of ideal form, very large size, excellent flavor, and exceptional tenderness. It is one of an almost endless number of variations, among which Mr. Burbank is able to select in continuing his experiments. The variety that produces this specimen, however, is well worthy of a place in the market-garden without further development.

of the lettuce, as one cannot be sure in many cases that a certain amount of the pollen does not remain to effect fertilization of some neighboring pistil.

I was able to combine some desirable qualities, but did not succeed in combining all the desired qualities in a single variety.

There is greater variation as to flavor among lettuces than is commonly supposed. Of course, the different types are used for different purposes and at different seasons. Those grown under glass must be compact growers, while those grown in the open may be permitted to develop larger heads. There are varieties of so-called perpetual lettuce which have been so educated that instead of running to seed they form new heads that can be cut again and again.

As to all these matters there is room for improvement, and there is opportunity for the plant experimenter whose experience justifies him in working with a somewhat difficult species to secure better varieties of this very popular salad plant than any at present on the market.

If it were desired to produce an exceedingly hardy variety of lettuce, it might be possible to hybridize the cultivated species with the wild lettuce.

I have never attempted to do this, however, as

An Aberrant Type

A comparison of this hybrid artichoke with the one shown in the preceding picture, will suggest how wide is the variation that may be shown in the form and arrangement of the bracts making up the flower-head. Here the bracts bristle in all directions, like bayonets, and the head lacks desirable compactness. Nevertheless an artichoke of this form might be thought of interest by a restaurateur in search of novelties.

the wild lettuce is a persistent and pestiferous weed which is hard to eradicate once it gains a foothold. It will grow and ripen seed in the corner of a brick wall when only a few inches in height; yet in a good location will grow seven or eight feet in height. It produces seed in vast numbers.

But, of course, it is not the seed of the ettuce that the gardener is seeking, and it remains to be seen whether a combination of the wild with the cultivated one, even if hybridization could be effected, would result in useful variations.

Dandelion and Thistle

There are other wild species of the composite family, however, that offer greater inducements to the cultivator. One of these is the familiar dandelion, a plant usually regarded as a weed, but really having possibilities of usefulness.

The dandelion is sometimes used as a green vegetable in the early spring by country folk in various parts of the United States, but it is perhaps nowhere cultivated. In France, however, a successful attempt has been made to produce a dandelion that has much thicker, larger, and more abundant leaves than those of the wild plant.

This developed form is sometimes cultivated there and attains a certain value as a market vegetable.

A Wild Artichoke

It will be seen that this wild artichoke, in full bloom, is hardly three inches across. The flower-head as a whole is strikingly suggestive of that of the thistle. This specimen gives a very good idea of the manner of flower from which the modern improved artichoke has been developed. Contrast this little flower with the giant in the next picture.

The great difficulty which stands in the way of cultivation of the dandelion is its exceeding prolificness. The heads of the flower will ripen even when the plant has been pulled up by the roots. It is even alleged that the plant will develop seed when the flowers are not pollenized. This and the capacity to ripen seeds from the unopened bud makes the plant peculiarly difficult to eradicate, and it becomes an almost intolerable pest in lawns.

Should an attempt be made to cultivate the dandelion, therefore, the aim should be to develop the leaves at the expense of the flower. Doubtless it would require long series of experimental efforts, but in the end it would probably be possible to develop a dandelion that would produce an abundance of large, succulent leaves somewhat as the lettuce does. Meantime the tendency to excessive flower production could be restricted.

At least two other members of the Composite family that rank as weeds, and are generally held to be obnoxious, deserve to be named as offering possibilities of usefulness if properly educated. These are the thistle and the burdock.

That the thistle is a succulent herb that browsing animals have found palatable, is proved by its development of an elaborate system of protective thorns. Of course, these thorns must be

The Improved Burbank Artichoke

Contrast this mammoth blossom with the relatively insignificant blossom of the wild artichoke. The front of this wonderful flower is twenty inches across. It bears scant resemblance to the wild prototype; except, indeed, that the essential flower organs at its center have the same thistle-like appearance. So striking a modification has been brought about only through long cultivation; but the Burbank artichokes have made giant strides in a few generations.

eliminated if the thistle is to be transformed into a garden vegetable. The thistles are not a whit more thoroughly cursed with thorns than the artichoke was when first brought under cultivation; and not more so than some of the recessive artichoke seedlings are at the present day, even when grown from the most carefully selected stock.

I have grown the thistle extensively from seed, and although I have worked more especially for variations in color of the flower, yet I have paid attention also to the quality of leaf, and I am quite convinced that it would not be difficult to produce a spineless variety.

Indeed my experiments have advanced far in that direction.

I am convinced also that the leaf and stock of the plant may readily be developed so as to make a palatable vegetable, comparable in its uses to spinach.

It is known that some of the thistles are palatable when cooked, tasting not unlike the dandelion. There is a thistle raised in South America that is quite extensively used as food, and there is a California thistle with a variegated leaf that is sometimes eaten. These two are certainly as good as greens. Without a doubt their palatability could be increased by selective breeding, and this, with the removal of the thorns,

A Field of Hybrids

The very marked improvement that Mr. Burbank has been able to effect in the artichokes in his garden within recent years has been in considerable measure brought about by crossbreeding different races. Such crossing has of course been followed up by rigorous selection, and the result is a great variety of artichokes of very striking qualities of size and form of flower-head, and of flavor. Some typical specimens are here shown.

would give us a new garden vegetable of a type at present rather sparsely represented.

There is also an Old World thistle, known to the botanist as *Carduus marianus*, that has found its way to this country, growing wild by the roadsides in California, that is sometimes used for cooking.

The flower buds, roots, leaves, and leaf-stalks of this plant are edible—a very unusual exhibition of versatility scarcely duplicated by any vegetable under cultivation. As this European thistle is not distantly related to the French artichoke, and as it is edible even in its wild state, it would seem to furnish good material for the experiments of the plant developer. I have observed that cultivation and freedom from crowding increase the size and succulent qualities of this plant enormously. In other words it responds to cultivation readily. I have thought many times of improving it, and even yet may undertake to do so.

I have done a good deal of work with a related naturalized weed from Europe, of the genus *Sonches*, known as the sow thistle.

The genus is closely related to the lettuce, and not distantly related to the artichoke. The two species with which I have worked are succulent weeds that vary greatly as to their degree of smoothness of leaves and stem. One of them is

More Material for Selection

There is almost endless variety of size and form and flavor about the artichokes in Mr. Burbank's modern colony. Some of those already developed are approaching perfection, as we have seen; others, like the present specimen, show interesting possibilities, and will be utilized in further crossbreeding experiments; for with the artichoke, as with other horticultural products, there is merit in new varieties, even when varieties already in hand have attained relative perfection.

commonly known as the prickly sow thistle. But the two species are so crossed that it is hardly possible to find one in California now that is not hybridized. Such at least is my observation.

I have worked on the smooth-leaved hybrids, which are highly nutritious, making excellent greens.

The plants can be raised with the utmost ease, and varieties were produced from these wild hybrids, by selection and cross-breeding, which were far superior to any specimens seen in the wild state.

So marked was the improvement that I was somewhat disposed to introduce the developed smooth-leaved sow thistle as a garden vegetable, but hesitated to do so lest I should be blamed for introducing a weed. The cultivated plant retains its ability to produce a superabundance of seed; which are drifted here and there by the wind. So it might escape to the field and become a pest. This of course is a danger that must be faced in the case of any wild plant brought into the garden.

But it should not be forgotten that all of our present garden plants were at one time wild, and that the tendency to superabundant production of seed is likely to be lost when the plant is pampered by cultivation.

I have also worked with a very fine species of

Sonches from New Zealand. I found it more difficult to raise than the ordinary *Sonches.* Possibly by combining the two a plant might be developed that would lack the objectionable qualities of undue hardiness and prolificness. At least the experiment is worth making.

Improving The Burdock

As to the burdock, doubtless the very mention of its name suggests a highly objectionable weed. And, indeed, the common burdock, as it grows by the roadside, after it comes to maturity is not an inviting plant. And by its objectionable burrs the plant is known and judged rather than by any other characteristic of the plant itself.

But there are Japanese cousins of the burdock that are cultivated and have produced large and rather tender stalks and also long, fat roots which are highly prized as food.

At an early stage, while these stalks retain their tenderness, they are not unpleasant to the European or American palate if when partially cooked the water that has extracted the bitter principle is removed and the cooking is continued with fresh water. The root is most used in Japan where it is considered one of their most valuable vegetables.

The young, tender roots are offered for sale when about eight to twelve inches in length and

Swiss Chard

This relative of the beet is not very well known in American gardens in general; but it has been given much attention in recent years by Mr. Burbank. The specimens in his garden, as will appear from this photograph, are of large size and luxuriant growth; but they are still undergoing development. It is only in recent years that Mr. Burbank has given the chards especial attention.

an inch or more in diameter. They contain less of the bitter principle than do the leaf stalks.

The stalks themselves, at their edible stage, are about the size and form of an ordinary leaf stalk of the rhubarb. Several of these Japanese burdocks have been grown on my grounds, where the American burdock has also been cultivated more or less for the last twenty years. I have noticed a great variation in the bitterness of the stalks of the plants.

Under cultivation they have never become troublesome weeds, as the common burdock has become in the Eastern United States.

They respond readily to the effort to improve them, and I entertain no doubt that if a systematic attempt were made to develop them along the right lines a most valuable vegetable might be produced, which would be appreciated by those who live in a more favored climate.

The lines of selection should look to the production of a plant with large fine roots, or for a reduction of bitterness, which is the most objectionable quality of this plant.

To anyone who has given little thought to the subject it may seem more or less absurd to talk of the development of useful qualities in such weeds as these. But whoever has a clear conception of the extent to which the vegetables now in our

gardens have improved under cultivation will see possibilities in such plants as the thistle and the burdock that are not revealed to casual inspection.

Poisonous plants like the tomato and the potato have been made wholesome within comparatively recent times.

The thistle and burdock have no poisonous principle. Some species are wholesome and not unpalatable even in their wild state, and all that is required is to accentuate the good qualities that the plants already possess in order to make them worthy of membership in the coterie of garden vegetables.

—It should not be forgotten that all of our present garden plants were at one time wild, and that to the wild we must look for countless new garden plants in the future.

Winter Rhubarb— and Other Interesting Exotics

The Possibilities When Plants Are Brought From The Tropics

THE story of the development of the Winter Rhubarb was told in an earlier chapter. It will be recalled that the plant came to me from New Zealand, and that in its original form it had a small and inconspicuous stalk and was of slight commercial value. It will further be recalled that by selective breeding I developed the stalk until it was of large size and of exceptional succulence.

Meantime, the changed conditions of another hemisphere, with the transposition of seasons, disturbed the habit of bearing of the plant in such a way that it ultimately became practically a perpetual bearer, its time of greatest productivity, however, being the winter season. After the Winter Rhubarb had been developed and put upon the market, I continued my experiments in selective breeding as well as in hybridization. The

new rhubarb, as was stated in the earlier chapter, proved variable when grown from seed.

The tendency to winter bearing, however, was pronounced, whatever variations the plant might show as to other qualities.

In more recent years I have continued the development, and have produced new varieties of the Winter Rhubarb that differ so markedly from the original one as to merit introduction as separate varieties.

The new rhubarbs have been developed by crossing the Winter Rhubarb with various races of ordinary rhubarb, in particular with the improved variety known as the Burbank Giant. The crosses were made mostly with the use of the Winter Rhubarb as the pistillate parent, but reciprocal crosses were also made. The progeny, as is often the case with hybrids, showed great vigor of growth.

The individuals varied as to many of their qualities, and I presently sorted out no fewer than thirty-six different types, all of them of gigantic size.

The best of these has been introduced under the name of the New Giant Crimson Winter Rhubarb.

Qualities of the New Rhubarb

Not only does the improved Winter Rhubarb

Burbank Rhubarb

The story of Mr. Burbank's development of the Winter rhubarb and its improved variety, the Giant Winter rhubarb, has been told in another volume. It will be recalled that the progenitor of the Winter rhubarb came from New Zealand, but took on new capacities for development under the changed conditions of the California soil and climate.

produce stalks at all seasons of the year, but these stalks are of such quality as to give this rhubarb a place apart among garden vegetables.

The stalks have the pleasant taste of berries, and they altogether lack the tough stringy quality of the ordinary rhubarb.

Meantime the stalks are as large as can be conveniently handled and shipped, being two or even three feet in length, and from an inch to an inch and a half in thickness. The beautiful crimson color of the stalks adds to their attractiveness.

An important quality of the improved Winter Rhubarb is that a plantation can be obtained from a few plants in a fraction of the time required to stock it from older varieties. It is only necessary to dig up the plants in the fall, September being the best month, dividing them with a sharp knife, cutting them into the smallest possible bits which have even a single bud and a fragment of a root.

Each fragment will make a big, hardy, and productive plant in a twelve month; and it often happens that the smallest fragments will produce the largest plants.

Another way to propagate the plant, if you do not wish to injure the old plantation, is to dig away the earth around the plant and cut out little V-shaped pieces of the roots, one or two inches long, with a sharp knife, including a bud. Each

of these pieces will make a big plant in the course of the year, and the old plant will produce larger stalks, though in somewhat reduced number, as the result of this treatment.

In this way a plantation of the Giant Winter Rhubarb may be extended indefinitely without injury to the old crop.

Of course, the new plants grown thus from pieces of root or from root bulbs will reproduce absolutely the qualities of the original plant.

If an attempt is made to extend the plantation by sowing seed, a good deal of variation must be expected, as this plant, like so many other cultivated ones, is not fixed for reproduction from seed. In the matter of winter bearing, however, all the seedlings will reproduce the qualities of the parents. The seedlings may vary in size, quality, form of leaves, and somewhat as to color of stalks and various minor points; but never in the matter of winter bearing.

They will reach their time of fullest productivity in midwinter, several weeks before the ordinary rhubarb begins to be productive.

The plants fruit the first year from cuttings or when raised from seed, and two generations a year from seed to seed can be raised by forcing in the California climate; but of course such forcing is not recommended.

Another Bed of Burbank Rhubarbs

Although the first Winter rhubarbs were developed by selection, Mr. Burbank subsequently used hybridizing experiments, with good results. He has experimented with a great variety of rhubarbs, and has found this plant a tractable and a peculiarly interesting pupil. Observe the prolific and compact growth of the specimen here exhibited.

Unfortunately the Giant Winter Rhubarb is not hardy enough to grow except in regions where the eucalyptus, the orange, and the fig can be grown out of doors. I am working with the plant in the expectation of producing hardier varieties, but for the present it must be confined to warm climates, unless it is grown in the greenhouse. It is reported in the East that the new Winter Rhubarb does not respond well to the forcing methods of the greenhouse, so I do not recommend it for that purpose, although I see no reason why it should not grow under greenhouse conditions, as a cool greenhouse may practically duplicate the conditions of California where the plant is at its best.

It will not stand soaking with water for any length of time, but in our California soil there is absolutely no loss from any cause, the Giant New Rhubarb being a much surer producer than any other variety of the tribe.

Forcing the Rhubarb

It is well-known that the ordinary rhubarb may be forced in the greenhouse, and made to produce out of season by first freezing the roots. Curiously enough, after this treatment, the root develops its stalk, granted the right conditions of soil, almost equally well in the dark.

Mention is made of this possibility of forcing

the rhubarb by inducing abnormal conditions lest a statement of the earlier chapter in which the habits of the new variety are explained should be misinterpreted.

I referred there to the impossibility of changing the habits of the ordinary rhubarb, and permanently extending its period of bearing, by merely altering the conditions of cultivation. It is of course possible to cause almost any plant to germinate out of season by greenhouse treatment. Such treatment, however, has no influence on succeeding generations.

The plant caused to grow out of season merely responds to the abnormal surroundings in which it is placed, and will immediately revert to the habits of its tribe when placed under normal conditions.

But the crimson Winter Rhubarbs in all the perfected varieties produce their main crop in the winter, and continue productivity throughout the entire year, because of the reappearance of a latent tendency to perennial bearing; and this revived tendency is thoroughly fixed. As already stated, plants retain this tendency when grown from seed, however they may vary in other regards. So there is no analogy whatever between the winter-bearing habit of these new rhubarbs and the abnormal habit of winter bearing that may be forced on an

Burbank Asparagus

It is almost superfluous to say that Mr. Burbank has not neglected so popular a garden vegetable as the asparagus. In point of fact, this plant, like practically all the other garden favorites, has come under Mr. Burbank's guidance, and has shown marked improvement through selective breeding. The picture suggests the quality of this improved Burbank variety. The stalks here shown are as succulent and savory and tender as they look.

individual plant of the old variety by growing it under hothouse conditions.

Incidentally, the fact that the old rhubarb to be forced successfully in the greenhouse must be frozen furnishes another interesting illustration of the value of a period of absolute rest or dormancy for a plant, and will suggest analogies with other cases of the same kind elsewhere cited. Seemingly the tissues of the plant root, having been frozen even for a brief period, have no way of estimating the length of time during which they have remained dormant, and thus are ready to respond to the climatic conditions about them when thawed out. So, finding themselves in the atmosphere of the springtime, they begin their regular springtime growth.

In a sense, the artifice of the gardener may be said to fool the tissues of the plant, and to cause it to take on an altogether abnormal activity.

But, as just stated, this result applies only to individual plants, and no one thinks of developing a race of Winter Rhubarbs in this way.

Mixed Heredities

The habit of perpetual bearing, as manifested by my perfected varieties of Winter Rhubarb, was explained as a development based on the comparatively recent residence of the ancestors of the plant in a tropical climate. The fluctuating tem-

South American Peanuts

The peanut, notwithstanding its popular name, is not regarded as a nut, but is in reality borne on a leguminous plant, and therefore rather closely related to the peas and beans. The picture shows a specimen of a variety of peanut from South America that Mr. Burbank has taken in charge to see if anything notable can be done with it.

peratures of the globe in successive ages—a time of tropical warmth being succeeded by an ice age —resulted in subjecting the plant at different periods to wide extremes of temperature.

A vast number of species were in this way wiped out of existence.

But those that survived developed powers of resistance which were in many cases subsequently lost when the plants migrated to the tropics, or when tropical conditions prevailed; but which remained as latent influences in the germ-plasm, susceptible of being brought out again under proper conditions of hybridization.

Thus, in order fully to understand the anomalous habit of the new Winter Rhubarbs, it is necessary to recall that their immediate ancestors came from another hemisphere, and that traits of their latent heritage from remote ancestors both of tropical and sub-Arctic habit were brought to the surface under influence of the new conditions of environment to which they were transplanted; and the further influence of new crosses and of constant selection through many generations.

All in all, the new Giant Crimson Winter Rhubarb is a plant that presents points of interest for the student of heredity and for the practical plant developer, no less than for the practical horticulturist. And for the latter—whose interests, of

Another View of the South American Peanut

The great range of variation shown by these South American peanuts suggests indefinite possibilities of improvement through selective breeding. Even in the first generation or two considerable improvement has been observed, and Mr. Burbank expects that marked development will occur in the course of a few succeeding generations. In his hands, the peanut seems likely to prove as tractable as the peas and beans.

course, are those of the public at large—the new rhubarb has been declared to be "the most valuable vegetable production of the century."

The merit of that characterization we need not discuss; but no one who has seen the new Giant Rhubarb is likely to dispute that it is a plant of altogether exceptional interest.

Some Esculents and an Anomalous Solanum

The rhubarb is one of the few plants in which the edible portion, for which the vegetable is prized, consists of the leaf stalks.

There are a good many other vegetables, however, in which the stalk of the leaf, along with the leaf itself, becomes a more or less valuable food product. Such, for example, are the cabbage and its allies, the lettuce, and some others that we have already considered, as well as the spinach and the celery.

A familiar example of a plant whose stem furnishes a valued food product if cut at an early stage, before it puts out its leaf stalks, is the asparagus.

These plants have interest from the standpoint of the experimenter and all present certain opportunities for improvement. I have grown them all, and have done something in the way of selective breeding with most of them, but these experiments have been relatively insignificant as compared with

my work in other lines, and there is little to record in connection with the work with either the spinach, celery, or asparagus that would have novelty or value. The methods of growing these plants are well known, and there is opportunity for development of new varieties either along the lines of selection or of hybridization.

But the rules of selective breeding, as already given and repeatedly illustrated in connection with other vegetables, will sufficiently guide anyone who wishes to work with these.

There is a tropical plant of a quite different order, however, to which I shall merely refer, because I myself have not experimented with it very extensively, but because work of considerable interest has been done with it by others, that will illustrate the possibilities of development of tropical plants even when grown in relatively inhospitable climates. The plant in question is the not unfamiliar *Solanum* known as eggplant. Very interesting work in experimental breeding has been done with this relative of the potato and tomato by Professor Byron D. Halsted of the Experimental Agricultural Station of New Jersey. It involves no principles, however, that have not been fully exposited in connection with other plants, and for details of the work the reader may be referred to Professor Halsted's annual Bulletins.

A Field of Celery

The picture gives a very good idea of the best method, or one of the best methods, of packing the celery with dirt for bleaching. The celery plant in its normal condition contains a mildly narcotic principle, and it is necessary to bleach it completely before it is fit for the table. The experiments that Mr. Burbank has made with the celery have been chiefly in the way of selective breeding, without crossing.

The nightshade family has other members seemingly worthy of development, that have been given scant attention.

One of the most interesting of these obscure relatives of the potato and tomato and eggplant is the not unfamiliar but seldom cultivated plant known as the Ground Cherry, sometimes dubbed also Husk Tomato.

The Interesting Ground Cherry

The little plant in question belongs to the genus *Physalis,* and it has numerous close relatives that inhabit various parts of the world. One of these. the *Physalis alkekengi,* or strawberry tomato, has been under cultivation for a long time. The fruit is small, yellow, sweetish, and insipid. Other species have been received from Japan and Korea, and also from India.

I have grown several varieties of the common species of ground cherry from time to time for the past forty years.

In general the fruit of the plant appears to be a curious misfit, the husk not being large enough to contain the fruit when ripe, and thus splitting open to expose the fruit itself, which thus becomes subject to cracking and splitting.

I have attempted through cultivation and selection to remedy this fault; and I have also attempted to cross the ground cherry with other

species, but I have had no success in either direction.

I have made hybridizing experiments not only with the common species and the foreign ones already mentioned, but also with other species from the west coast of Mexico, and from Arizona and Texas. But hitherto I have been unable to secure a single hybrid.

The plants grown from the seeds received from my collector, Mr. Walter Bryant, in Western Mexico, have husks of the most delightful fragrance. The aroma clings to the husk for months. It has no connection with the fruit itself. This form has proved the most difficult of all the ground cherries to germinate from seed, or to grow after the plants are produced. It is well worthy of attention, even if grown solely for the fragrance of the husks. But in addition to this, the fruit is of good quality.

It is about the size of the ordinary ground cherry, but a little more orange in color.

Even at the present stage the fruit of the ground cherry is sometimes used for making pies, puddings, and preserves. The Peruvian species in particular produces a great quantity of superior fruit. There is sufficient variation between the different species to afford abundant material for development. If hybridization could be effected, there is every reason to suppose that greatly

A Cousin of the Cabbage

The kale plant is a very close relative of the cabbage, being, in point of fact, one of several related plants that have probably developed from the same wild stock, greatly modified through long generations of cultivation. Of the various cabbages, kale is perhaps the least generally known. For that very reason it should have exceptional interest for the amateur worker in the vegetable garden.

improved varieties of the ground cherry could be developed.

The lack of success of my hybridizing experiments should not be considered as by any means definitive. My final success in hybridizing two species of this particular family after unsuccessful experiments extending over a quarter of a century will be recalled in connection with the story of the development of the Sunberry. There is every reason to suppose that experiments systematically carried out would result in finding different members of the ground cherry tribe that could be hybridized.

And the prospect of producing a really notable fruit from such a union—a fruit not unworthy of a relative of the potato, tomato, and sunberry—seems particularly good.

Improving the Passion Flower for Its Fruit

There is another vine, known everywhere by name at least, and famed for its flowers, that has fruit possibilities that have been almost totally neglected. This is the celebrated Passion Flower, a plant represented by a few species of tropical and sub-tropical habitat, of which two at least wander as far north as the southern portion of the United States.

The name Passion Flower was given to these plants by the early Spanish missionaries, because

they thought they saw in the blossoms an emblem of the crucifixion.

According to an early description of the blossoms, the filaments were thought to resemble a blood-colored fringe suggesting the scourge; the column in the center was said to represent the cross; the filaments on which the pollen sacs were borne, three in number, represented nails; and a peculiar arrangement of floral organs encircling the top of the blossom did service for the crown of thorns.

To complete the picture five spots or stains of the color of blood found on the petals were said to represent five wounds.

That the symbolism might lack nothing of completeness, it was noted that the leaves of the plant were shaped like the head of a lance or spear; and that there are round spots on the leaves that might be taken to represent the thirty pieces of silver, the price of the betrayal.

The merits of this symbolic characterization need not concern us. But doubtless the name served to draw unusual attention to the flower, although the intrinsic merits of the flower itself are of a high order. As a hothouse vine, it has been cultivated everywhere, and is often regarded as an important acquisition. Meantime it runs wild as a trailing vine in regions where the win-

The Egg Plant

These specimens suggest very vividly the wide range of variation in the fruits of the egg plant of different varieties. Such variation always suggests inviting possibilities for the plant developer. The egg plant responds readily to the efforts of the gardener, and no small degree of interest attaches to the efforts to isolate and fix varieties of peculiar form.

ters are not too severe; and in some regions it is so abundant as to be considered a weed, notwithstanding the beauty of its flower.

The genus *Passiflora,* to which the Passion Flowers belong, is made up largely of vines and shrubs, but there are a few members that grow to the size of trees.

The best flowering varieties are strictly tropical, and do not thrive in the northern climates. But, on the other hand, the species that bear the larger and more edible fruits are relatively hardy. Doubtless there is a casual relation between these facts. Possibly the tropical species do not find it difficult to propagate their kind, and have not found it necessary to develop succulent fruits. In any event, it is fortunate from the standpoint of the plant developer of the temperate zones that the fruit-bearing members of this particular tribe are the ones that are hardy enough for introduction in our climate.

In point of fact, the common species of the Northeastern United States, locally known as the Maypop, is so thrifty a plant that it becomes a very troublesome weed.

It spreads in all directions by its underground root stalks, and it roots very deeply. It is almost as difficult to eradicate as the perennial morning-glory. Deep plowing of the soil is about the only

method of destroying it when it is once introduced. But this very thriftiness may become an advantage, once the plant has been sufficiently transformed to assume position as a valuable fruit bearer.

This common Maypop was the plant with which my experiments in developing the fruiting possibilities of the Passion Flower began. But my interest soon extended to other species, including the best Australian varieties of at least three species, and a number of new species from South America that were not named by my collector and have not been identified.

One of the most promising Australian species is known as *Passiflora edulus*. It produces a much larger quantity of fruit than the Maypop, but is less hardy than that plant. Several of the South American species are too tender to be grown even in California. One of these, known as *Passiflora ccurules*, bears a fruit about the form and size of a small watermelon, yellowish-green in color, with an attractive edible pulp. I have cultivated this species, but it has not entered to an important extent into my experiments, because of its extreme tenderness.

The fruit of the species with which I have chiefly worked is usually about the size of a hen's egg.

Passion Flower in Bloom

The passion flower has great popular interest because of the curious configuration of its essential parts, and the symbolical meaning associated with them in the minds of the superstitious. In Mr. Burbank's garden, however, the passion flower is cultivated not so much for its blossom as for its fruit. Varieties are being developed that give good promise of producing a fruit of marketable quality.

The usual color is orange-yellow, but some varieties have a purplish tinge, and a purple pulp. Some of the species of the Southern Hemisphere are recognized as producing valuable fruit, particularly for combination with other fruits, having a pleasing and unique flavor. But the fruit of the Maypop has seldom been considered worth picking.

My experiments with the passion flowers began about 1895. I found it not difficult to grow the plant from seeds received from different regions. It is only essential to keep the ground warm and moist. There is an astonishing difference in the growth and vigor of the different seedlings. Moreover, some of the vines produce ten or even twenty times as much fruit as others, and the flavor of the fruit varies from exquisiteness to entire insipidity. Some specimens have a large amount of edible pulp, while others are made up almost entirely of skin and seeds.

The seedlings usually bear during the second year, or at latest the third.

The fruit does not ripen to advantage unless the weather is very warm.

So from the outset I selected those seedlings that bore earliest in the season, attention being given also, as a matter of course, to the size and flavor of the fruit, and to the attractive qualities

Flower and Fruit on the Same Plant

This interesting picture shows the Passion Flower bearing blossoms and green fruit and ripe fruit at the same time. This interesting peculiarity suggests that when the fruit is developed it will have an exceptionally prolonged season. Many different species of passion flower have been utilized by Mr. Burbank in hybridizing experiments, in his effort—which give every prospect of success—to develop a valuable new type of fruit.

of the flowers—for I had in mind a plant that would have not only great value as a fruit bearer, but also a recognized place among ornamental vines.

The passion flowers show wide range of variation, and thus furnished at the outset abundant material for the operations of the plant developer.

But in addition to this I found it easy to hybridize the different species, thus ensuring further variation. The pollen sacs and the pistils are very prominent, and it is easy to effect pollenization by removing the prominent bright colored stamens from the flowers of one and dusting the yellow pollen on the prominent pistils of the other.

I have given particular attention to hybridizing the Maypop with the Australian species, *Passiflora edulus,* already referred to. I thought it would be possible to combine the good fruiting qualities of the Australian species with the hardiness of the American species. The fruit of the former has a thick, hard, shell-like covering over the pulp, and a fragrant and highly flavored interior. That of the latter has a thin, husk-like covering, with a minimum amount of edible matter.

Cross-fertilization was readily effected, and the experiment gives every promise of a successful issue.

Several hundred hybrids that have not yet

borne fruit are now under observation. Not all of these are hybrids of the Maypop and the Australian Passion Flower, but the seedlings of this cross at present appear to be most promising. The work has not been under way long enough to give anything like final results. But what has been done indicates that it is at least worth while to continue the experiments.

Indeed, there seems to be little doubt of a thoroughly successful and satisfactory issue.

Possibly it may be necessary to bring other species into the combination through further hybridization, but the material at hand is ample, and the fact that almost every variation may be found among the seedlings gives full assurance that if the experiment is carried out with sufficient zeal, it will be possible to assemble the best qualities of the different species in a new variety.

The renewed vigor given by the hybridizing of species from different parts of the world will tend to increase the size of both the plants themselves and their fruit, and the quality of the fruits already secured leaves it scarcely open to doubt that the final product will be of positive value.

—Every plant on earth is here to serve our purposes—if we but train it in the service.

A Bed of Camassias

The camassia is, as a glance at this picture will show, a plant having no small measure of interest as a producer of ornamental flowers. But it has also an edible bulb; and Mr. Burbank is endeavoring to improve this bulb in size and quality. The measure of success already attained is shown in succeeding pictures.

The Camassia—Will It Supplant the Potato?

And Other Tubers of Value for Food

FOR the most part plants are cultivated for a single quality.

If a plant produces beautiful flowers, we do not usually demand that it shall also produce valuable fruit. We do not ask that a plant which produces a valuable fruit like the tomato shall also produce tubers like the potato. It is only by accident rather than by special design or selective breeding on the part of man that a certain number of plants, notably members of the rose family, produce beautiful blossoms and delicious fruits as well.

The apple-tree in full bloom is indeed a beautiful object, but the apple would probably be raised quite as generally as it is if its blossoms were altogether unattractive. The Japanese, to be sure, have developed the blossoms of their fruits, but

in so doing they have usually neglected the quality of the fruit itself.

And as to garden vegetables, about the only member of the clan that is cultivated for its flower as well as for its edible product is the Pink Chive that I have recently developed.

There exists a tribe of plants, however, of which we have hitherto made no mention, that possesses qualities of flower-bearing of a high order, combined with the capacity to produce roots of such quality of edibility as to suggest competition with our best tuber bearers, including the potato itself.

These plants are certain wild members of the lily family that have no colloquial name except that given them by the Indians; a name that has been variously transcribed as Quamash and Camass. From this name the botanist has developed the generic title *Camassia*. The not altogether unappropriate name of wild hyacinth is sometimes given the species that grows in the Eastern United States.

But it will be most convenient in speaking of the tribe to adopt the generic name of Camassia, in lieu of a better.

The various species of camassia grow wild in rich moist meadows and along small streams. All the species are hardy. The leaves of the plant are

Individual Camassia Blossoms

It will be seen that the camassia has a really attractive flower. This is an unusual qualification for a plant that is making bid for a place in the vegetable garden. There are several species of camassia available for purposes of the plant developer.

usually lance-shaped, about three-quarters of an inch in width, and of length varying according to the fertility of the soil, usually from eight to sixteen inches. The flower stalk in ordinary soil varies with the different species from eighteen inches to nearly four feet in height.

The flowers are usually purple, blue, or white. In some of the new hybrid species the color has changed to rose, and in others it inclines toward crimson.

All the camassias are bulbous, of course, like other members of the lily family. But there is a great difference in the size of the bulbs among the different wild species, and, as will appear presently, there is enormous variation when the different species are hybridized.

Hybridizing the Camassias

My experiments on a large scale with the Camassia have been carried out for more than twenty years, and have included work with five species.

So far as I am aware, no one had undertaken to improve any of these until my experiments were instituted, about 1890.

My first work was done with a species known as *Camassia Leichtlinii,* which grows abundantly on Vancouver Island. Considered as a flowering plant this is the finest of the native varieties. It

grows almost altogether in crevasses of rocks, but it produces very attractive large, deep purple flowers, with wide petals. First the attempt was made to improve the flower, and I introduced a good many years ago a modified variety of the species that was somewhat dwarfed as to leaf and stem but in which the flowers had been much enlarged, the petals broadened, and the color changed to a dark blue.

As my experiments continued, however, my interest in the camassia increased, and I began to give attention to the bulb of the plant as well as to the flower.

I began working with another species, the *Camassia Cusickii,* which has relatively large bulbs; and with another of the well-known nature species, *Camassia esculenta,* the bulbs of which are much smaller but of recognized edible quality.

Most of my work in hybridizing and selective breeding has been done with the three species just named, but I have also raised somewhat extensively two other species, known as *C. Howellii* and *C. Fraseri,* as well as a great number of wild varieties of all the different species from British America, Washington, Oregon, California, and Nevada.

From the outset individual plants were selected of each species and variety that were the best I could obtain. Here, as so often elsewhere, I was

Hybrid Camassia

The picture shows color variation in one of Mr. Burbank's hybrid camassias. Mr. Burbank intends to retain and accentuate the good flowering qualities of the camassia, even while giving especial attention to its bulb. This makes the process of selection somewhat complicated, but it presents no insuperable difficulties, as the reader who has followed Mr. Burbank's experiments in other fields is aware.

enabled to produce considerable improvement merely by selecting individual plants that showed the most desirable qualities of flower and bulb, destroying the inferior ones. From the outset careful attention was paid both to the flowers and to the bulbs, as I desired to produce plants that would be ornaments in the flower garden and at the same time would grow enormous bulbs that would make them valuable acquisitions to the vegetable garden.

Having secured the best representatives of each species and variety by selection, I began an extensive series of hybridizing experiments.

I found it a relatively simple matter to hybridize the different camassias. All the species seemed to combine quite readily.

The characteristics shown by the hybrids are those that experience with other plants led one to expect. In the first generation, there is relative fixity, and the greater or less dominance of one parent or the other. In the second generation, the hybrids break up into numerous forms, varying widely as to color of leaves, height of stalk, and size of flowers, as well as in form and size and quality of bulbs.

Some of these hybrids of the second generation produced bulbs smaller than those of their progenitors.

But others grew bulbs of enormous size. Even

to one who is accustomed to observe the striking variations that are produced through hybridization, it was surprising to see the extraordinary impetus given to the bulbs of the camassia by the union of different species.

The bulbs of the common edible species, *C. esculenta,* are relatively insignificant, usually growing about one-half to three-quarters of an inch in diameter. The *C. Cusickii* produces the largest bulb of all, but it is large only in a relative sense, being usually little over an inch in diameter and two inches in length.

But among the second generation hybrids were some that produced bulbs three and a half inches across and four or even five inches in length.

The difference was about that between an English walnut and a large turnip.

In viewing these gigantic bulbs, sprung thus from dwarf ancestors, one was reminded of the gigantic hybrid walnut trees that came of the union of Persian and California walnuts; of the mammoth Phenomenal Berry; of the Giant Amaryllis; and of sundry other hybrids that were stimulated to excessive growth of stem or fruit or flower by the union of parents of just the right degree of affinity.

Flower and Bulb Improved Simultaneously

Meantime I had taken pains to cross dark flow-

The Wild Camassia

This is one of the wild camassias that furnish material for Mr. Burbank's hybridizing experiments. A comparison with earlier pictures will suggest the measure of improvement that has already been attained in connection with the flower. Succeeding pictures will show the response that has been made by the bulb.

ers with dark flowers, and white ones with white, and pink with pink, wherever possible, so as to intensify the various types.

As already noted, there is a pronounced tendency to variation even among the wild species, all the camassias sometimes producing pale greenish, almost white, flowers. These, if grown from seed and carefully selected, can be changed to snowy white. Some of the variations secured bear flowers that are truly white, while others that are called white are really of a pale greenish hue. The seedlings of these greenish white ones tend ordinarily to produce blossoms that revert to the pale blue color of the species from which they were derived.

So the production of a truly white camassia required continued selection—a process of gradual intensification.

But of course hybridizing facilitated this process. It also gave opportunity for selection with regard to flowers having broad petals—narrowness of petal being one of the original defects of the camassia as a flower. Moreover, a number of extra petals have been added in some cases, and it is only a matter of time until double camassias will be produced.

All along the line, then, the flowers of the camassias have been improved by selecting from

among the best of the hybrids. Twenty thousand bulbs have been under observation at the same time, and improvement has been rapid.

In the end, the camassia will prove to be an ornamental plant of distinct value, highly prized for its flowers.

But it will be prized also for its bulb, which, in the developed and selected hybrids, is assuming satisfactory proportions, as already pointed out, and which has undoubted food value, surpassing the potato even, both as to nutriment and flavor. And of course the work of development in this direction is only at its beginning. The results already attained justify the expectation that the bulbs of the developed camassias will be of really notable size, constituting a garden vegetable of very exceptional food value.

The wild camassias generally produce but few offsets. But some of the hybrid ones not only produce numerous offsets, but tend to divide like the garlic, sometimes making five or six enormous bulbs in a season. Of course this habit has been carefully encouraged among the seedlings, as this rapid multiplication will be of obvious importance when the camassias are grown either for bulbs or for flowers.

I have also successfully hybridized some of the camassias with certain of their relatives, the squills

A Contrast in Bulbs

Here is one of Mr. Burbank's improved camassia bulbs, contrasted with the bulb of one of its wild progenitors. It will be seen that the hybrid has attained relatively gigantic size, while holding pretty closely to the general type of its parents. Of course attention is given constantly to the edible qualities of the bulb, no less than to size.

(genus *Scilla*), of which I have imported many species from South America. The two tribes hybridize readily. The hybrids showed conspicuous changes in the bulb. The outside covering of the bulb of the squill is whitish, while that of the camassia is usually darker. The hybrids showed more compact bulbs of a lighter color than those of their maternal parent, the camassia.

But there are all gradations in the bulbs as to color and other qualities.

I have worked very extensively with the squills, but with reference solely to the development of the flowers, with results that will be outlined in another connection. Here I refer to them only as suggesting that these plants may be of value in introducing new qualities into the strains of hybrid camassias, stimulating further variation, and thus giving opportunity for betterment both of bulb and flower.

It is too soon to predict just what place these improved camassias may take in the vegetable garden. But the experiments have progressed far enough to show that the species has hitherto unrecognized possibilities.

Meantime a plant that is almost equally attractive from the standpoint of florist and market gardener is an anomaly that must make wide appeal to the horticulturist.

There are twenty or more species of plants belonging to the lily family wild along the Pacific Coast that make up a group which the botanist classifies under the generic name *Brodiaea.*

There are allied plants in South America, regarding the precise classification of which there is some difference of opinion. But for the purpose of the horticulturist the entire group may be ranked under the name of *Brodiaea.* The plants have not been extensively cultivated until recently, and they have received no popular name.

The different species vary greatly in form, size, and arrangement of the flower. The color of the flower is usually either blue or rose or purple, though sometimes white. There is also a crimson-flowered climbing species, known as *Brodiaea volubilis,* which somewhat rarely becomes white.

Crossing the Brodiaeas

I have crossed this climbing species with the species known as *Brodiaea capitata,* and with various others. Some of these crosses produce most beautiful flowers intermediate between the parents. Unfortunately the best hybrids were destroyed by gophers before I had opportunity to save the seed. The interest of the brodiaeas in the present connection hinges on the fact that the plants have bulbs or corms that when cooked are very acceptable as food. Several of the species,

A Wide Range of Variation

Here are camassia bulbs small, large, and medium; thick, thin, and spindle shaped. Obviously there is plenty of material for selective breeding. Where such variation occurs, still greater variation will be shown in some of the crossbred descendants. Moreover the flavor of one, the form of another, and the size of a third may be combined in a single descendant; and all the good qualities may then be accentuated through selective line breeding. The camassia promises to furnish a very valuable addition to the rather small list of edible bulbs.

especially the *Brodiaea lactea,* are relished by the Indians, and are often dug and eaten by children. The bulbs of some species contain a very high percentage of starch, probably greater than that of the potato.

I have worked on the *Brodiaea lactea* to increase the size of the bulbs. When growing wild the bulbs are only about half an inch in diameter. By selective breeding, varieties have been originated that will produce bulbs two inches or more in diameter. The plants can be grown almost as thickly as lawn grass, and it is probable that the yield per acre of the bulbs could be made to equal a good crop of potatoes.

In developing the brodiaea for this purpose, it would be well to search carefully for bulbs that grow to unusual size in the wild state—there is considerable variation in this regard.

The brodiaea is well worth cultivating for its flowers alone, and it would appear that the plant offers possibilities of combining flower-production with the production of a valuable food. Unfortunately, however, there is a complementary relation between the seed and the bulbs, and in order to secure bulbs of the largest size, it is necessary to remove the seed stalk before blossoming time.

Whether cultivated for flowers or for bulbs, the brodiaeas are very interesting plants that give

great promise of improvement under the hands of some careful experimenter.

It is a little difficult to cross them. I have produced many hybrids, however, and it is said that occasional hybrids are found where two wild species are growing in the same neighborhood. They all bear seed abundantly, though it takes three, four, or even five years from seed before they bloom.

They grow by thousands on each square yard of ground, appearing almost as thick as grass on a well-kept lawn.

In the same species there is a good deal of variation in the form and size of the flower. On the heights of the Sierras, the *Brodiaea lactea* grows only a few inches high, whereas in the valleys it grows to a height of eighteen inches or two feet.

Along the alluvial creek banks *Brodiaea Laxa* grows very large and tall, with handsome clusters, while on the mountain sides it is dwarfed.

Even plants of the same species in the same locality vary widely as to size of flower.

Brodiaea capitata grows abundantly along the roadsides, and especially in grain fields. It blooms and produces seed before the grain is cut. *Brodiaea terrestris* has a stem so short that the flowers almost rest on the ground. The blossom is just the

Some Almost-Edibles

Here we have a group of Watsonia and lily bulbs, some of which are approaching a stage of edibility. Lily bulbs for the most part are provided with a bitter principle, to protect them from insects and various subterranean marauders; but some species are much less bitter than others, and it would doubtless be possible to get rid of the bitter principle in time, by careful selective breeding; and an edible bulb might result. There are numberless undeveloped possibilities of improvement along these lines among the bulbous plants.

color of a blue violet, and the clusters may be mistaken for violets at a little distance.

In other localities the *Brodiaea terrestris* bears flowers some of which have a white stripe. Sometimes half the blossom may be white, the other part deep blue. Sometimes five or six blossoms will be blue, and a single one white. In other cases the proportions are reversed.

I have not observed any in the wild state that could be called pure white, but by cultivation and selection pure white varieties have been produced.

I have worked extensively on the *Brodiaea capitata*, the species just mentioned as growing in the wheat fields. On a poor dry soil this plant grows about two feet in height, and on long, straight, slender, wiry stems. But on good soil, especially in the wheat fields, it sometimes grows to the height of three or four feet, or even more, bearing a much larger cluster of blossoms.

In looking over a field of brodiaeas of this species, one may expect to find one in ten thousand, or perhaps one in twenty thousand that is almost white. Seedlings raised from these produce a variety of flowers, white, pale or dark blue, and striped; with a constant tendency to revert to the blue when first taken under cultivation.

By selection and re-selection I have produced strains which invariably come white, and by the

same process have produced varieties with flowers twice as large as the ordinary, also making the flower-head larger, and the plant a much more rapid multiplier from the bulbs.

From all this it will appear that the brodiaea is a very interesting plant. As already suggested, it well deserves the attention of some careful experimenter, who might develop certain strains for flowers and others for bulbs. Plants that are of interest both to the lover of flowers and to the vegetable gardener have exceptional claims on the plant developer.

Other Neglected Lilies

There are two allied tribes of plants known as *Bloomeria* and *Brevoortia,* respectively, that are closely related to the brodiaea, and each of which is of interest.

The brevoortia is usually called the Floral Firecracker, from its green, crimson, and yellow flowers. I have grown these plants extensively from seed, to produce new varieties, but the experiments were carried out only to the extent of increasing the yellow and crimson colors.

I have grown the *Bloomeria aurea* extensively, and have made minor improvements in it through selection. The plant has a bulb like the brodiaea, growing deep in the earth in dry, sandy places. In the wild state the stalks vary in height, and there

Blossoms of the Brodiaea

The brodiaea is another wild plant Mr. Burbank has brought into the garden, and which he is educating with an eye to both its blossoms and its bulb. Some of the wild brodiaeas are edible, and Mr. Burbank expects to improve on their qualities through hybridization and selection. Some rather notable first steps in this direction have already been taken. It will be seen that the brodiaea has an interesting, even if not a very spectacular flower.

is also a slight variation in the color of the flower. So there is opportunity for selective breeding. Moreover, I judge from physiological characteristics that the plant should cross readily with the brodiaea, although I have not attempted to make the cross.

It is almost certain that improved varieties might be obtained by hybridization.

There is a bulbous plant called *Alstroemeria,* that is botanically related to the Amaryllis rather than to the true lilies, which offers possibilities of tuber improvement. The plants are natives of Western South America. I grew seedlings and hybrids by the ten thousand for several years, and became convinced that if the roots and tops could be taught to grow in a more compact form this would become a very popular flower, and perhaps also a very valuable food plant, as the roots are sometimes eaten and are quite palatable and nutritious. I have worked on the species known as *A. Chilensis, A. pulchella,* and *A. Brasiliense,* and subsequently on a large number of new species from Chile.

A great variety of colors and combinations occur in the hybrid forms that may be fixed by selection. I am endeavoring to obtain a more hardy strain with improved flowers and more compact growth.

The Chilean Alstromeria

Yet another plant that combines the qualities of beauty of flower with those of a possibly edible root. In this case, as will be seen, the wild flower has notable claims to beauty. Under the hand of the plant developer, it will probably become an exceptionally handsome flower; and the bulb also gives good promise of proving adaptable.

At one time I crossed plants of this genus with the California lily (*Lilium pardalinum*) and had several hybrids, but the root and the bulb did not make a good combination. The plants bloomed one year, then died. The hybrid blossom was smaller than that of the lily, and it resembled that of both parents in being speckled and in its combination of colors. The hybrids that blossomed produced no seed.

The long, slender, white tubers of the *Alstroemeria Chilensis* are edible. This plant grows in very dry soil, and is peculiarly adapted to some of the California soils and climates. It is at present too tender for growth in the Eastern United States, but it is possible that through hybridization and selection it may be rendered hardy, and in that event this may become a valuable garden vegetable.

The Epau Potato

The lilies and their allies are not the only wild plants with bulbs or roots that are edible and susceptible of improvement.

On the contrary there are several plants of different families that offer noteworthy possibilities in this direction.

There are, for example, tuberous varieties of the genus *Carum*, relatives of the caraway, that grow on the Pacific Coast, especially toward the

Another Type of Alstromeria

There are various races of alstromeria, and Mr. Burbank is experimenting with as many of them as he can secure. He will follow his usual method of hybridizing, followed by selective line breeding. He is rather sanguine as to the outcome in the case of the alstromeria. The experiments, however, have not yet reached a definite stage.

Northwest, the roots of which are relished by the Indians.

One species in particular, called the epau potato, is dug in great quantities in the fall and stored for winter use. The roots are small, almost like those of the *Ranunculus* (cowslip, etc.), and are similar in form to the roots of the dahlia, though much smaller. They have a sweet, aromatic, and pleasant flavor. In different localities they vary a good deal in size and quality. There are places where the plant grows almost like grass, so that hardly a shovelful of dirt can be turned over without exposing numerous roots.

When brought under cultivation, the epau potato appears susceptible to the influences of its new surroundings. The roots increase greatly in size and in succulence.

I have gathered the seeds and roots of this plant, and have from time to time had seeds sent me from many localities, during the past fifteen years. The best seeds came from Idaho. Plants grown from seed sent from Idaho developed into herbs four feet in height, producing roots three to four times as large as most of the California *Carums,* and seeding quite as abundantly.

I have been able by selecting individual roots to improve the species known as *Carum gairdneri* quite rapidly. I have observed that when the

blossoms are removed, so that no plant energy is required for the production of seeds, the roots are much larger. This is an interesting compensatory effect that illustrates the close correlation between the different parts of a plant, and in particular the reliance of the roots on the leaf system.

There are, as already stated, several species and numerous varieties of the plant that could be used for hybridizing purposes, and doubtless the tendency to variation could thus be accentuated.

A very large number of plants can be grown on a small piece of ground, and if the roots could be developed even to one fourth the size of those of the carrot, this would prove a very valuable addition to the list of garden plants. The roots are not only nutritious, but they have exquisite flavor even when raw; and they are improved by cooking.

I think the plant very well worthy of improvement and general cultivation.

—The lilies and their allies are not the only wild plants with bulbs or roots that are edible and susceptible of improvement—there are many noteworthy possibilities in this direction.

Potato Seed Balls

The potato does not ordinarily go to seed, but when it does the fruit resembles a miniature tomato, as this picture will suggest. It was through finding such a seed ball on the Early Rose potato that Mr. Burbank developed the now celebrated potato that bears his name.

The Potato Itself—Who Will Improve It Further?

No Plant Is Ever a Finished Product—Potato Suggestions

THE story of the Burbank potato has been told many times. But it has seldom been told correctly. Like stories in general, it gains or loses something almost every time it is repeated, and it sometimes comes back to me in a guise that is scarcely recognizable.

The real story of the production of the Burbank potato is very simple. Something of the economic value of the discovery has been suggested in an earlier chapter, and will be touched on again before we are through. The importance of the discovery to me personally has also been suggested. It constituted my first commercially valuable plant development, and furnished a practical means of coming to California, where, doubtless, my experiments have been carried out on a far more comprehensive scale than they ever would have been in New England.

[Volume VII—Chapter IX]

Yet, on the other hand, I have always been disposed to think that if the potato had not furnished a means of migrating, and pointed out the possibilities of plant development, both these ends would have been accomplished by some other member of the garden or orchard family. Still there is a wise old proverb about praising the bridge that has carried you over, and for me, assuredly, the new potato served as a most important bridge.

So I naturally look upon the development of the Burbank potato as marking an epoch in my life, and as standing quite apart from other plant discoveries.

In the sense that it was my *first* important plant discovery, it must always remain the *most* important one.

A Simple Development

Considered as a problem in plant development, the origin of the Burbank potato was a relatively simple matter. There is no story of complex hybridizations and elaborate series of selections to be told in connection with it, such as we have heard in connection with sundry other more recent discoveries. Indeed the word discovery may be applied with peculiar propriety to the origination of the Burbank potato, because it all came about through the chance finding of a seedball growing

Bodega Red Potatoes

The Bodega Red was the standard potato in California before the coming of the Burbank; and it is still extensively grown. This picture gives a good idea of its characteristic form and appearance, and of the quality that gives it its name.

on the stem of a potato vine among numerous other vines in an ordinary garden.

Of course the observant eye was there to note the anomaly of a potato producing a ball of seeds in defiance of the usual Early Rose potato traditions. Also there was the receptive and inquiring mind of youth, to challenge the product and raise the question of what would result if these seeds were planted. These qualities, or something akin to them, must always be present where new phenomena are under observation, else no discovery would be made however lavishly the materials for discovery are laid before us.

In many of my later discoveries, I myself brought the materials together and had a share in combining them and in directing and guiding the processes of nature through which new plants were developed. In the case of the potato, as just stated, all this work was done quite without my co-operation.

When I came upon the seedball it was far advanced toward perfection, and my task consisted merely of watching it and making sure that the seeds were gathered and preserved, and in due course planted.

A Seedball Lost and Found

That the story should not altogether lack picturesqueness, I must record that my incipient

discovery came very near being rendered futile by the accidental loss of the all-important seedball after it had been revealed.

I had first seen the seedball, growing on an early rose potato vine, some time before it came to maturity. My mind was at once impressed with the idea that this might sometime be of value, inasmuch as this potato had never been known to bear seed. Moreover, I had for some time been on the lookout for potatoes that would offer opportunities for development, as those that were grown in the neighborhood at the time did not fully meet my ideas as to what a potato should be in form, size, color, production, and keeping qualities.

This was as long ago as 1872, and it should be understood that at that time the potato, as ordinarily grown, was a tuber much smaller in size and less smooth and attractive in appearance than the ones with which the present-day grower is everywhere familiar. Moreover, the potatoes were wont to suffer from what was called dry rot.

Of course the average gardener accepts the product of his vines and herbs somewhat as he finds them, with no clear notion that they could be made different from what they are.

But I had been imbued from the outset with the idea that inasmuch as existing plants had evolved from inferior types, it should be possible

Sprouting Bodegas

One of the faults of the Bodega is that it sprouts too readily. Even if kept in a paper bag, it may sprout abundantly, as shown in this picture. Of course the sprouts draw on the food material in the potato itself, and injure the tuber as a table vegetable.

to develop any or all of them still further. So my general attitude of mind toward the garden products was that of a workman handling plastic materials. And, as regards the potato, I had a very clear notion that the ones we raised might be very distinctly bettered if only the right way could be found.

So the hint given by the seedball was instantly taken and day by day the ripening of this precious little receptacle was watched with the utmost interest and solicitude.

Judge of my consternation, then, on visiting the potato patch one morning—with the thought in mind that now, probably, the seedball would be ripe enough to pick—to find that the coveted fruit had disappeared.

With anxious attention I parted the vines and searched everywhere for the missing seedball. I went over every inch of the ground for many feet on all sides. But I could find no trace of the missing seedball.

I was obliged finally to give up the search for the day, reluctantly admitting that I should probably never see again the little ball of seeds on which such high hopes and expectations had been based.

Yet I could not believe that the seedball had been carried away, for no outsider visited the gar-

den, and no one would have taken the slightest interest in the tiny fruit in any event. So day after day I returned and took up the search again. I covered the ground systematically in every direction, moving each vine, and anxiously scrutinizing the soil about its roots, and lifting every chance leaf under which the little seed receptacle might have lodged.

And at last this patient search was rewarded. Several feet away from the original vine, snugly lodged at the base of another vine, the missing seedball was found.

Whether it had been removed by some bird that had plucked at it inquiringly, thinking that it might furnish food; or whether some stray dog running through the potato patch had quite by accident broken it off and projected it to where it was found, I never knew. It sufficed that I had the precious seeds again in my possession, and I took good pains to see that they were safely stored for the winter.

On removing the seeds from the capsule, it was found that there were twenty-three of them. The coming of spring was eagerly awaited to reveal what hereditary possibilities were stored in these seedballs.

Twenty-Three New Varieties

When spring came, I planted the seeds out of

Snake Potatoes

A glance shows why these curious Mexican potatoes are given the popular name of Snake potatoes. It is more than likely that the wild progenitor of the cultivated potato had some such form as this. Mr. Burbank is experimenting with the potatoes here shown, to see whether they have possibilities of development.

doors, as one would plant the seeds of beets or cabbages. The ground had been prepared with great care, and each seed was placed about a foot from its next neighbor in the row. But no special protection was given the seeds.

To-day I would not think of planting valuable seeds of any kind in this way. The risk would seem far too great.

I should now plant them in boxes, after the manner described in the chapter on the care of seedlings, and give them individual attention in the greenhouse. As I look back upon the incident, I have often wondered that I was able to sleep at night while my precious seeds were thus exposed to any marauders of the animal or insect world that might chance to come upon them.

But a good many times it happens that we pass quite safely and unwittingly through dangers that seem very threatening indeed when we look back upon them. And so it was with my twenty-three potato seeds. Every one of them sent a sprout through the soil in due course, and put out its tiny cotyledons, and grew into a thrifty vine. And although no vine of them all produced a seedball, each one developed a fair complement of tubers.

Needless to say I watched their growth with solicitude, tentatively digging into a hill here and there as the season progressed, to note what such

Chilean Wild Potatoes

Here are wild potatoes from South America, of forms various and sundry. There are numerous species of potato still in the wild state, and Mr. Burbank has secured such of them as his collector could find, and has tested them all in selective and in hybridizing experiments. The results have in some cases been very promising, but on the whole have been rather disappointing.

a novelty as a potato grown from seed would be like.

Interesting developments were expected, but no one could have any very clear idea as to what these developments might be. But I certainly had not expected so remarkable an exhibition as that which met my eyes, when, late in the fall, the day came for digging the potatoes, and each hill in turn was carefully spaded and made to reveal its treasure.

For as we went down the row, spading up one potato hill after another, we found in each successive hill a different type of tubers. One hill would show small potatoes of curious shapes; another hill, larger potatoes with deepset eyes; yet another, potatoes red in color, or with rough skins, or knotted and covered with bulbous tumors.

But there were two vines that bore tubers that were instantly seen to be quite in a class by themselves.

These were very large, smooth, white potatoes, excelling in all respects any vegetables of their kind that I had ever seen.

The product of all the other vines but these two could be at once discarded. At best they only equaled the average potatoes of the early rose stock from which they sprang. But the two exceptional vines bore tubers that quite outrivaled

even the best example of the parental stock. Not only were they superior in size, but they also excelled in symmetry of contour, in whiteness, in uniformity of size, and in productiveness.

Among the twenty-one discarded potatoes there were, indeed, a few that were not without interest. One variety was red, and not unattractive, but it had not proved very productive, and most of the tubers decayed soon after they were dug. So this variety was obviously unworthy of further attention. Another vine bore potatoes that were pinkish in color, and having eyes so prominent that the long slender tubers seemed to be all eyebrows, the eyes reaching quite to the center of the potato. Yet another was round and white, but too small to be of any value.

As between the products of the two exceptional vines, there was not a very marked difference. The tubers from one averaged slightly larger than the other, slightly more uniform in size, just a little smoother and more attractive in appearance —in a word, in every way just a shade better.

These best tubers were, of course, carefully preserved, and a considerable crop was grown from them next year by dividing the tubers and planting them in the usual way. And their progeny, multiplied year by year, until they are now gathered by millions of bushels each season in all parts

Mexican Potatoes

These wildlings have the characteristic potato quality, notwithstanding their peculiarity of form and their uninviting exterior. They are far from being what would be considered, in a comparative sense, a valuable table product, however. It is interesting to note their resemblance to certain potatoes grown by Mr. Burbank on vines on which tomato tops have been grafted.

of the world where this vegetable is grown, constitute the Burbank potato.

Introduction of the Burbank

The twenty-three seedlings were grown, as just noted, in the season of 1873.

The one incomparable member of the lot proved itself in the following season, and gave a goodly quantity of tubers all substantially identical with the original ones and obviously quite different from the usual potatoes then in existence.

It required no very keen eye to see that a prize had been secured. But I did not at first know just what to do with it. I desired, of course, that the new potato should be introduced to the general public, realizing the economic importance of a potato that would produce two or three times as many bushels to the acre as the ordinary varieties, and at the same time give individual tubers of superior quality.

But the first dealer to whom I offered the new potato declined it rather curtly, and I had some diffidence about approaching another. Finally, however, I mustered courage to bring the new potato to the attention of Mr. James J. H. Gregory, then a resident of Marblehead, Massachusetts.

By way of introduction, I sent him a sample of the new potato.

Mr. Gregory tested the potato by planting it,

and was so pleased with the result that he sent word next season that he would be glad to talk with me. Accordingly I went to see him. I looked forward with pleasure to the visit, as Mr. Gregory had an interesting garden and a very complete seed establishment. But I was a little diffident about going, and so persuaded a friend, the Hon. J. T. Brown, then a banker in Lunenburg, to accompany me.

I shall always entertain the most vivid and pleasing recollections of the day spent in Mr. Gregory's gardens, and of the hospitality extended by the owner and his family.

Mr. Gregory showed a basket of beautiful potatoes, which he declared to be quite the best he had ever seen, and which, he assured me, were the product of the sample I had sent him. He asked me to sell the potato to him outright, giving him the exclusive right of introduction of the new vegetable. And that, of course, was precisely what I wished to do.

The matter of terms was not so easily adjusted. I had thought that $500 would not be more than a fair price for the new potatoes. But Mr. Gregory said that $150 was the most that he could pay. Other new potatoes were being developed, he said, and this one would not have the monopoly that it might have had a few years earlier. Had

Selecting Seedling Potatoes

It will be observea that Mr. Burbank has the potatoes dug up and left in the hill for inspection and identification. The particular specimens here shown chanced to be second generation seedlings of the Chilian wild potatoes. There are promising possibilities in some of the lot.

I developed it even two or three years sooner, he could have paid a thousand dollars for it.

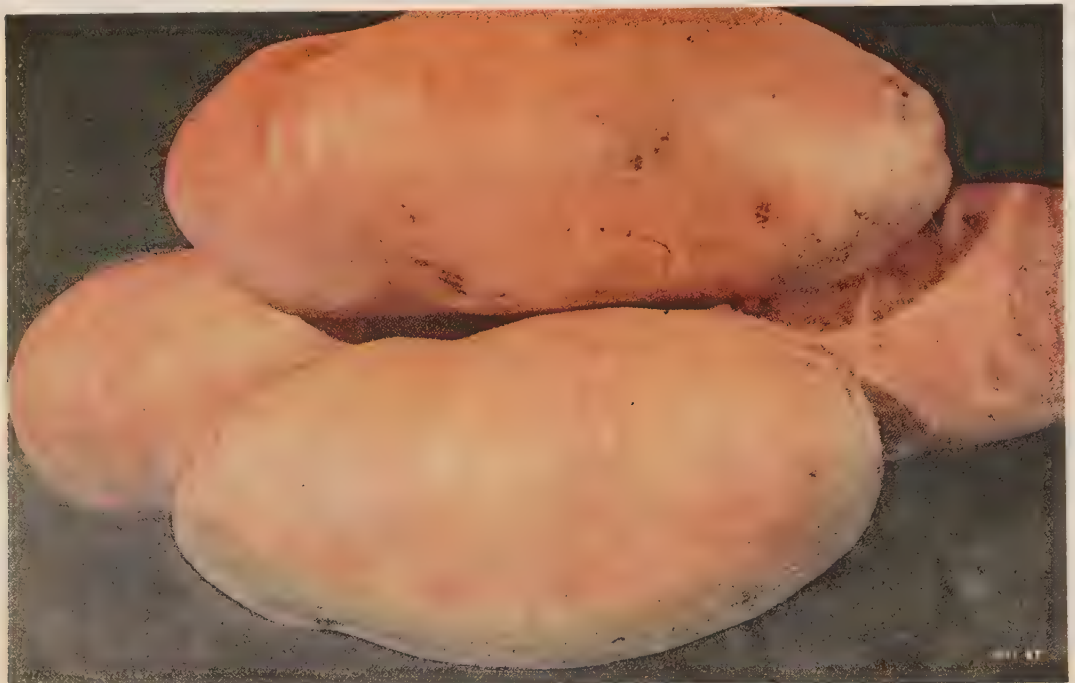
I was perhaps a little disappointed, but was contented to accept Mr. Gregory's verdict, and let him have the potato without looking farther. With the $150 that he paid, I came to California next season, having first delivered to Mr. Gregory a crop of the potatoes raised on my own ground and a neighboring piece of land.

Mr. Gregory permitted me to keep ten potatoes. These I brought to California, and thus introduced the Burbank potato on the Pacific Coast. The name "Burbank seedling," I should explain, was given the potato by the purchaser. Mr. Gregory stated afterward, in a letter now before me, that he chose this name because he decided, "after pondering over the matter, that the one who originated such a variety deserved to have it bear his name."

Progress of the Burbank

It is not necessary here to trace the story of the spread of the Burbank potato from one region to another until its annual crop has been estimated to have a value of not less than seventeen million dollars.

Suffice it that I personally introduced it in California, and that after the prejudice against a white potato had been overcome, the merits of



Salinas Burbanks

Salinas may be said to be the home of the California Burbank. Here entire regions are given over to the cultivation of this potato, and fine representatives of the variety are produced in enormous quantities. The picture shows some typical specimens.

the new tuber were so quickly recognized that the Burbank came to be the standard tuber on the coast from Alaska to Mexico. The U. S. Department of Agriculture aided in the distribution of the Burbank at an early day, sending it to various states, among others to Oregon, where it soon became exceptionally popular.

The Burbank does its best on well drained, sandy soil, and in a moderately cool, moist climate. It thrives splendidly in the Sacramento and San Joaquin Valleys.

There are single farms that raise from one hundred to one thousand acres each of Burbank potatoes; indeed, I received a visit recently from a gentleman who stated that his crop of Burbanks covers two thousand acres.

In the region of Salinas, California, the conditions seem to be exactly suited to this potato, and the crop sent from this region brings a price so exceptional that the Salinas Burbank has come to be regarded as the standard for quality in California.

Over six million bushels of the Burbank potato were produced on the Pacific Coast alone in the season of 1906, and the crop of that year probably did not differ greatly from that of each year of the past fifteen or twenty. In more recent years it has doubtless at least held its own.

Russet Burbanks

These Burbank potatoes, raised by Mr. Lou D. Sweet, of Denver, Colorado, have somewhat modified their coat, in a way that does not add to their attractiveness. It is said, however, that this particular variant is peculiarly resistant to blight, which gives it exceptional value.

Of course all the Burbanks making up the enormous crop of the world have been produced by multiplication of the original single hill of tubers that grew from the one best vine among the twenty-three seedlings of the original potato seedball.

That the enormously multiplied product of to-day maintains everywhere the characteristics of the original, offers an interesting proof that varieties do not "run out" if grown under suitable environments.

How Explain The Burbank?

But how shall we account for the original variety itself?

I have told the story of its development without offering any explanation of the interesting phenomena observed. It remains to account not alone for the Burbank but for the twenty-two other varieties of potato that were its seedball sisters but which were allowed to perish, because they did not, on the whole, possess qualities that justified their preservation.

Our studies of plant development through hybridization, in connection with numerous species of flowers and trees and orchard and garden fruits, supply clews that make the explanation of the origin of the new potatoes relatively simple.

Some Selected Seedlings

Mr. Burbank's experiments with potatoes have been continued throughout the entire period since he developed the Burbank, more than forty years ago. Until recently he had failed to produce any variety that seemed, on the whole, to excel the Burbank itself. Some recent seedlings, of mixed parentage, have very admirable qualities, and several of them are being introduced.

We have seen that a tendency to variation is everywhere introduced when different species or varieties of plants are hybridized. And although no conscious experiment in hybridization was involved in the case of these potatoes—inasmuch as I had no knowledge of the seedball until it was in actual existence—yet it is clear that nature had performed the experiment, and that I was enabled to take advantage of the results of her experimenting.

To be sure it is more than likely that the seedball with which I worked was produced by accidental fertilizing of the pistil from which it grew by pollen from a neighboring plant; representing, therefore, the crossing of individuals of the same variety and not a true hybridization of different varieties; for all the potatoes in my garden were of one kind—namely the Early Rose.

But the Early Rose potato is itself a crossbred variety. I am not sure that its exact history is known, but undoubtedly it is the product of the crossing of some other varieties of potato. The Early Rose was a seedling of the Early Goodrich, a white potato named after its originator, a clergyman who had been carrying on experiments in crossing the potato and raising seedlings.

The crossing from which it originated occurred

The Early Rose

The Early Rose is a well known and deservedly popular variety of potato that has held its own pretty consistently for half a century. It has exceptional interest from the standpoint of the plant breeder, because it was the variety that bore the seed ball from which the Burbank was raised.

on the grounds of Mr. Goodrich many years before the time of its discovery.

But of course that does not in the least matter, for every potato of a given variety, no matter how far removed from the original specimen of that variety in point of time, is of the same generation with that original so long as all are grown from the tuber.

All this has been clearly explained again and again in dealing with the propagation of other plants from tubers or cuttings or grafts or by root division.

It follows that the twenty-three seedlings were progeny of the second filial generation of the original varieties that were crossed and which produced the Early Rose. And this fully accounts for the extraordinary range of variation that the twenty-three seedlings manifested.

We have seen many illustrations of this tendency to vary in the second filial generation of hybridized species or varieties. We have observed that the latent qualities of diverse strains of ancestors are permitted to come to the surface and make themselves manifest in the various individuals of a second generation, once the tendency to relative fixity has been broken up by hybridization. So the twenty-three diversified varieties of potatoes that grew from the single seedball merely

Selected Early Rose

The Early Rose is a crossbred potato, but it holds remarkably true to type. There is a certain amount of variation, however, and it is possible to isolate improved strains by careful selection of seed potatoes. This specimen illustrates one of Mr. Burbank's experiments in this direction.

furnish another illustration of a principle that our studies in plant development have made familiar.

The case has interest, none the less, as presenting evidence from a new source of the application of a principle of heredity that can never fail to excite surprise however often we see it manifested.

It follows that we should not necessarily expect the Burbank potato to breed true from the seed, even if by rare exception a seedball should be formed on a vine of this variety. But in point of fact it breeds absolutely true as to color and reasonably true in form, but not one of the seedlings ever compared in its combination of good qualities with the original Burbank. But of course this is a matter of no practical importance. Probably not one potato grower in a thousand ever gives a thought as to whether the potato produces seed. In practice the potato is grown from the "eyes" of the tuber, and the grower gets approximately the sort of tuber that he plants. Beyond that the matter does not concern him.

Searching For New Varieties

But of course the plant developer must view the matter in another light.

He must consider the potato not as a finished product but as an important vegetable that may be susceptible of still further improvement. So for him, doubtless, the chief interest of the story of

The Burbank and Its Parent

At the left two typical Burbank potatoes; at the right two typical Early Rose specimens. As already noted, the Early Rose bore the seed ball from which the Burbank was developed. The difference between parent and daughter is explained by the fact that the parent is itself crossbred. The Burbank combines the qualities of some remoter ancestors.

the production of the Burbank variety must hinge upon what it can teach as to the possible production of still better varieties or of varieties adapted to different conditions of soil or climate from those under which the Burbank thrives.

The Secret of Further Improvement

Obviously the lesson of the Burbank is that all further improvement must be sought through the crossing and hybridization of the existing varieties of potato, and the raising of seedlings.

My own experiments in this direction have been extensive, and have led to some interesting results, even though the spectacular features of the production of the original Burbank have been lacking.

As early as 1895, I produced a hybrid between the Burbank potato and a variety known on the Pacific Coast as the Bodega red. This was advertised, but was never introduced. A variety that was introduced only a few years after I came to California was a sport that appeared in a field of Burbank potatoes growing on my brother David's place at Tomales.

There were five or six hills of vines that differed from the others in having larger tops and more vigorous growth as well as an altered appearance. They matured very late, and were found to have potatoes far less regular in outline than the ordi-

nary Burbank but much larger and coarser, and produced in great abundance. Next year they were introduced through a San Francisco firm.

But the potato did not differ sufficiently from the Burbank to maintain its individuality, and it is not now known as a separate variety.

My most interesting hybridizing experiments have been with the wild or half wild species of potato that are indigenous to various parts of subtropical and tropical America. An account of some of these experiments was given in Chapter 9 of Volume II, to which the reader is referred. There, to be sure, the experiments in hybridizing the potato were classified as failures, inasmuch as they led to no commercially valuable result. But it will be seen that they did not lack interest from a scientific standpoint. In particular some of the results in crossing the Darwin potato (*Solanum maglia*) with the common potato through which a vine was produced that bore a remarkable fruit, were cited at some length.

Interesting Hybrids

Here I may refer a little more in detail to results of this hybridizing experiment that were not mentioned in the earlier chapter.

The Darwin potato is a slender, erect-growing plant, bearing a tuber the flesh of which is usually bright yellow in color, and much subject to decay.

The Burbank Potato As It Grows

Observe the large even leaves of the Burbank. The abundant and vigorous foliage has a large share, no doubt, in explaining the admirable qualities of the tubers. The leaves, as we know, are the laboratory in which the starch is developed, and the potato without a good top cannot possibly have a good root system. Healthy leaves and healthy tubers are correlatives.

In its stem and blossom, also, the plant is quite different from the ordinary potato, and it commonly bears a seedball that is larger than the seedball that the cultivated potato bears on rare occasions; the seeds themselves, however, being much smaller.

I grew seedlings of the Darwin potato and improved them by selection until they produced tubers of enormous size, some of them weighing two to two and a half pounds. Then hybridizing experiments were carried out between the Darwin and the common potato.

More than half a million seedlings of hybrids between these two species were raised.

The Darwin potato is much more fixed in its characters than the cultivated potato, and these characteristics proved largely dominant in the progeny of the first generation, this dominance extending to the tubers themselves, which resemble their wild ancestor in size, color, irregularity of form, deep eyes, and tendency to decay.

Eight-Foot Vines

There were, however, some astonishing anomalies manifested by the hybrid progeny. Some of the vines grew so prodigiously that they reached eight feet in every direction from a single root; and the potatoes they bore grew on long stems or runners which spread nearly as far.

A Typical Hill of Burbank Potatoes

Here the tubers are exposed just in the position in which they grew. Some potatoes have the defect of developing sprangly roots, so that the tubers are widely scattered. The tubers of the Burbank are as compactly placed, almost, as eggs in a nest; greatly facilitating the gathering of the crop.

In other cases the vines were compact, in striking contrast with their straggling sisters.

As to the potatoes themselves, some were quite small, and the larger ones revealed the most curious colors—bright crimson, scarlet, bright yellow, white, black, and purple; the various colors being sometimes intermingled in the same tuber in the most curious way. Some were black from skin to skin, others had a red center with an outer layer of purple about a quarter of an inch thick. Others were white or yellow, with purple veins radiating from the center of the potato to the eyes.

In yet other cases the flesh of the potato was variegated with crimson and yellow, purple and white, blended into every imaginable form and figure; so that when the potatoes were sliced the effect was grotesque and sometimes fascinating, as the cut surface revealed landscapes, faces, geometrical figures, cloud effects, varying kaleidoscopically with each new slice.

Notwithstanding the great interest of these hybrids, I did not think them worthy of introduction, as they were curiosities rather than a practical commercial production. Yet it seems not unlikely that a more extended series of experiments in hybridizing and selection in which strains of the Darwin potato are introduced might result in a product of real value.

Some of the improved Darwin seedlings produced tubers of exceptional size, though as before stated, much subject to decay. If the breeding experiments were conducted along right lines it would probably be possible to produce in later generations a hybrid that combined the large size of tuber of the Darwin with the keeping qualities of the cultivated potato. It is really of great importance that the experiments should be repeated and carried forward to a successful issue.

What has just been said as to the curious results of hybridizing experiments with this species will sufficiently indicate that experiments of this kind will not be lacking in interest.

Experiments already far advanced at Santa Rosa, using the *Solanum Commersoni,* a species growing wild in the region of the Mercedes River, in South America, for a time gave great promise. The hybrids between this plant and the cultivated potato showed great improvement in some directions, but all the seedlings lacked one desirable character or another. The chief trouble was the bitter principle which was transmitted by the commersoni to almost all its hybrid seedlings.

I have, however, a very complex hybrid that is about to be introduced—the fruit is of a reddish color, almost apple shape. The plant is very productive, and the tuber is of fine quality.

The Perfect Burbank

A glance at this picture suggests why it is that Mr. Burbank has found it so difficult to improve upon the first potato that he developed. In size, form, contour, smoothness of surface, and reduction of eyes to the minimum, this potato approximates the ideal. The quality and flavor of its content is admirably in keeping with its exterior. All in all, it is a remarkable product.

There are various other wild Solanums growing, as did these original potatoes, in South America, that might advantageously be tested as to their hybridizing possibilities in connection with the cultivated varieties. It need scarcely be added that such experiments will ultimately be made in which all allied species of potato will be tested; and it is highly probable that this will lead to the development of new varieties of tubers that will surpass the potatoes of to-day as markedly as these surpass the wild ancestors from which they have been developed in comparatively recent times.

[End of Volume VII]

—I had been imbued from the very outset with the idea that inasmuch as existing plants had all evolved from inferior types, it should be possible to develop any or all of them still further.

List of Direct Color Photograph Prints in Volume VII

Peppers

Potatoes

Radish

Rhubarb

Roots

Seedlings

Soil

Squash

Tomatoes

Unicorn Plant

Vetch